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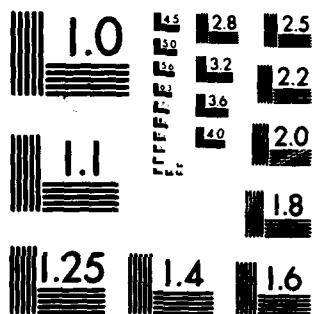
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**Biological Effects  
of Nonionizing  
Electromagnetic  
Radiation**

VOLUME IV

NUMBER 3

MARCH, 1980

**A DIGEST OF CURRENT LITERATURE**

A Quarterly Publication Produced for  
National Telecommunications and Information Administration  
and United States Navy

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**BIOLOGICAL EFFECTS  
OF NONIONIZING ELECTROMAGNETIC RADIATION**

Volume IV. Number 3.

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See also Volume 4.

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by

Biomedical Group, Science Information Services Organization

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# BIOLOGICAL EFFECTS OF NONIONIZING ELECTROMAGNETIC RADIATION

March, 1980 Volume IV, Number 3

## TABLE OF CONTENTS

Preface.....	v
Abbreviations and Acronyms.....	vii
News Items.....	1
Meetings and Conferences.....	5
Current Research.....	7
Current Literature.....	11
Authors of Current Literature Index.....	49

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## PREFACE

*Biological Effects of Nonionizing Electromagnetic Radiation* is a publication researched and prepared by the Franklin Research Center, Science Information Services Organization, under contract to the National Telecommunications and Information Administration (NTIA); funding provided by the U.S. Navy under interagency agreement with NTIA.

This digest serves as a vehicle through which current documentation of research highlights on the biological effects and health implications of nonionizing electromagnetic radiation (microwave and other radio frequency radiation) are compiled, condensed, and disseminated on a regular basis. *Biological Effects of Nonionizing Electromagnetic Radiation* is intended to be a highly useful current awareness tool for scientists engaged in research or related activities. The great number and diversity of relevant publications make imperative the availability of the service to persons whose work requires that they keep abreast of current developments in the field.

*Biological Effects of Nonionizing Electromagnetic Radiation* is published quarterly. The issues of Volume IV, and future volumes, will include materials received during the preceding three months. Each issue will include news items and announcements, a listing of meetings and conferences, abstracts of current literature, and a directory of current research. Materials for which full text is not available will be included as summary abstracts.

## ABBREVIATIONS AND ACRONYMS

A, amp - ampere(s)	NBS - National Bureau of Standard
Å - angstrom(s)	NIH - National Institutes of Health
BRH - Bureau of Radiological Health	NSF - National Science Foundation
C - centigrade	NIOSH - National Institute for Occupational Safety and Health
cm - centimeter(s)	NTIA - National Telecommunications and Information Administration
cps - cycles per second	NTIS - National Technical Information Service
dB - decibel(s)	Oe - oersted(s)
EPA - Environmental Protection Agency	OSHA - Occupational Safety and Health Administration
FDA - Food and Drug Administration	OTP - Office of Telecommunications Policy
g - gram(s)	PHS - Public Health Service
G - Gauss	rad - radiation absorbed dose
GHz - gigahertz	R - roentgen(s)
HEW - Health, Education, and Welfare	rpm - revolutions per minute
hr - hour	sec - second(s)
Hz - hertz	USAFSAM - U.S. Air Force School of Aerospace Medicine
IEEE - Institute of Electronic and Electrical Engineers	USDA - U.S. Department of Agriculture
IMPI - International Microwave Power Institute	UV - ultraviolet
IU - international unit(s)	V - volt(s)
J - joule(s)	VA - Veterans Administration
k - kilo--	W - watt(s)
l - liter(s)	Wb - Weber(s)
m - meter(s)	WHO - World Health Organization
m - milli--	wk - week(s)
M - mega--	wt - weight
mho - unit of measurement of conductivity	yr - year(s)
min - minute(s)	
mo - month(s)	
n - nano--	

μ - micro--

## NEWS ITEMS

### SCIENTIST DISPUTES USE OF SAR IN THE DEVELOPMENT OF THE C95 SAFETY STANDARD REVISION

Allan H. Frey of Randomline, Incorporated of Huntingdon Valley, PA, in a recent letter appearing in the *Bioelectromagnetics Society Newsletter*, disputed the use of the specific absorption rate (SAR) concept as a fundamental assumption underlying the development of the proposed revision of the C95 safety standard. Mr. Frey explained that the SAR concept assumes that the only mechanism whereby microwaves and other radio frequency energies can effect biologic systems is by the volume heating of a homogenous mass of tissue, and since the concept is nothing more than a calculated absorption rate in a tissue mass, it is doubtful whether the SAR has any relevance to the biologic organism at incident power densities  $<10 \text{ mW/cm}^2$ . Mr. Frey also disagrees with a secondary assumption that 70 MHz, the frequency for maximum energy absorption, is also the frequency for maximum sensitivity. He suggested that the biologic effects of low intensity energy observed at much higher frequencies would not necessarily have occurred at lower power densities at the 70-MHz region of the spectrum. Lastly, Mr. Frey considered that the use of the SAR concept in the proposed revision would ignore the effects of modulation and peak power. He added that some of his observations were supported by the results of a working group study, which met in February 1979. Mr. Frey concluded that "the assumption underlying the SAR concept renders it of little relevance to biological effects of low intensity or modulated energy which we are studying now. The application of the SAR concept in such studies is grossly misleading for both biologists and Regulators."

*Bioelectromagnetics Society Newsletter*, (10): 1; November, 1979.

abstract submission form from the Bioelectromagnetics Society, P.O. Box 3651, Arlington, VA 22203. Abstracts submitted by nonmembers must be sponsored by at least one BEMS member. May 1, 1980 is the deadline for submission of abstracts.

*Bioelectromagnetics Society Newsletter*, (10): 1; November, 1979.

### NEW YORK AGENCIES TO INVESTIGATE HARMFUL EFFECTS OF A POWER LINE ON RESIDENTS

Two New York state agencies have agreed to conduct a detailed study of the possible hazards that residents of northern New York face from a nearby 765-kV power line, which has been in operation for about 1.5 yr carrying Canadian electric power to New York. The agreement, between the New York State Public Service Commission (PSC) and the New York State Power Authority (PA), calls for the PA to spend as much as \$50,000 on a preliminary study to outline the full-scale research effort. The New York State Department of Health will assist with this study. Following the preliminary study and outline, research will be conducted to determine the possible harmful effects on humans and animals living near the line, which runs from near Massena on the U.S.-Quebec border to Utica, NY. The upper cost limit of the study will be about \$5 million, which is approximately 2% of the line's construction cost. Francis Rivett, a spokesman for the PSC, explained that the agreement provides funds for a laboratory study, with no experimental work on humans. Mr. Rivett added that the commission is interested in finding out "what, if any" effects are produced by the electric and magnetic fields generated by the line.

*Wall Street Journal*, p. 12; December 26, 1979.

### BIOELECTROMAGNETICS SOCIETY ANNOUNCES FIRST CALL FOR PAPERS FOR THE 1980 SECOND ANNUAL MEETING

The Bioelectromagnetics Society (BEMS) has announced the first call for papers for the 1980 BEMS Second Annual Meeting to be held September 14-18, 1980 in San Antonio, TX. Original papers are solicited for presentation in English (via platform or a poster session) on the interaction of electromagnetic energy (from 0 Hz through visible light frequencies) and acoustic energy with biologic systems. Areas of interest include: behavioral, physiologic, neurologic, endocrine, developmental, cellular and ultrastructural, and genetic effects; dielectric properties of biologic materials; electric field effects; exposure systems; dosimetry; diagnostic and therapeutic applications; interactive mechanisms; instrumentation; hyperthermia; and field perturbations. Authors wishing to submit papers should request an

### ANNUAL EUROPEAN MICROWAVE CONFERENCE—A CONTINUED SUCCESS

Since the first European Microwave Conference took place in London in 1969, the venture has enjoyed an expanded scope and prosperity beyond what its organizers might have originally projected. The 1979 conference, organized by Microwave Exhibitions and Publishers Limited, under the direction of Roger C. Marriott, was attended by 720 delegates; in addition, 320 separately registered delegates attended a workshop. The conference consisted of a full week of activities running from the 17th to the 21st of September. The program included a 4-day session of formal technical paper presentation, generally requiring parallel sessions, followed by a 1-day workshop. A trade show ran coincident with the 4-day technical presentation, with approxi-



mately 130 exhibitors, representing 241 companies. In addition, the technical committee, headed by Professor Peter Clarricoats, arranged for the presentation of papers by authorities in the microwave field. The invited papers were presented in advance of the technical session to avoid conflicts with other presentations. Jochen Edrich of the University of Denver, Colorado presented a paper on the use of microwaves for diagnosing and treating cancer. Other topics discussed included papers on microwave bipolar transistors, microwave communications from outer planets, and microwave holographic imaging. Having grown from a fledgling technical papers session to its present status, the European Microwave Conference now plans a full professional and industrial conference annually. Future conferences are scheduled as follows: 1980--Warsaw, 1981--Amsterdam (with a trade exhibit), 1982--Helsinki, and 1983--Brussels (with a trade exhibit).

*Microwave J* 22(11): 37-38, 40, 42-43; 1979.

#### BRH AND OSHA HOLD WORKSHOP ON RF SEALERS

More than 100 users, manufacturers, staff members of federal agencies, and representatives of employee and trade associations and public interest groups attended the BRH and the Occupational Safety and Health Administration's (OSHA) open workshop on radio frequency (RF) sealers. The workshop was held September 12-13, 1979 in Washington, DC to discuss the potential hazards associated with the use of RF sealers, heaters, and gluers, and to obtain information on techniques for controlling or eliminating hazards to personnel from these devices. The types of RF devices discussed generally operate at a frequency between 3-100 MHz and include heat sealers, fusers, molders, fasteners, and embossers; high frequency sealers and dryers; electronic and electromagnetic sealers and welders; and dielectric heaters. Among the specific topics addressed were: 1) measurement of stray electric and magnetic field intensities generated by RF sealers, 2) biologic effects of RF exposures at frequencies between 3-100 MHz, 3) the near-field conditions that exist during these exposures and the resultant difficulty of measuring the exposures and predicting possible adverse effects on exposed persons, 4) RF radiation measurement equipment and techniques that can be used at these frequencies, 5) procedures or techniques available for the control of stray RF emissions, and 6) possible initiatives of federal agencies regarding the control of RF-emitting devices. Representatives of the BRH, OSHA, NIOSH, the Federal Communications Commission, Canada's Department of Health and Welfare, and the University of North Carolina's Occupational Safety and Health Center presented talks on these subjects. The workshop was adjourned following a discussion session.

*BRH Bulletin* 13(26): 2-3; 1979.

#### LATEST BRH PUBLICATIONS SUBJECT INDEX IS RELEASED

The latest *BRH Publications Subject Index* (HEW Publication [FDA] 80-8070) has been issued by the BRH. This publication supersedes HEW Publication (FDA) 79-8070. The *Subject Index*, an abbreviated version of the *BRH Publications Index*, is revised and published several times per year and distributed annually. The *Subject Index* identifies publications by broad subject areas providing titles and FDA publication series access numbers as part of a BRH national program to control unnecessary human exposure to potential hazardous ionizing and non-ionizing radiation. To obtain information on the current availability of the *BRH Publications Subject Index* contact the BRH Technical Information Staff (HFX-28), 5600 Fishers Lane, Rockville, MD 20857 or (301) 443-3532.

*HEW Publication (FDA) 80-8070*, October 1979.

#### NINTH SUPPLEMENT TO THE BIBLIOGRAPHY OF MICROWAVE AND RF BIOLOGIC EFFECTS IS AVAILABLE FROM NTIS

The *Ninth Supplement to the Bibliography of Microwave and RF Biologic Effects* (DHEW [NIOSH] Publication No. 78-126), which lists approximately 575 additional references that were published up to September 1977, brings the total number of references of the world's literature concerning the biologic responses to microwaves (MW) and other radio frequencies (RF) to more than 4,600. In this *Bibliography*, particular attention is paid to the effects of MW and other RF on humans. The scope was broadened slightly from previous editions to include references to biologic studies of pure electric or magnetic fields, extremely low frequency fields, and ultrasound. Other entries cite biomedical studies involving electromagnetic pulse radiation, high voltage photography, biologic dosimetry, the effects of electromagnetic radiation (EMR) on cardiac pacemakers, EMR therapeutic applications, MW exposure regulations and standards, tissue fixation, insect control, and electroanesthesia. The citations are arranged alphabetically by author with sufficient information to retrieve the original document. Relevant presentations at technical meetings and anonymous reports are also cited, but in separate sections in the *Supplement*. The *Bibliography of Reported Biological Phenomena (Effects) and Clinical Manifestations Attributed to Microwave and Radio-Frequency Radiation: Ninth Supplement to Bibliography of Microwave and RF Biologic Effects* is an up-dated listing of the Naval Medical Institute Research Report No. 2, which was completed under Research Work Unit MF12. 524.-15-00048, October 1971. The *Bibliography* is available from the National Technical Information Service, Springfield, VA 22151.

*DHEW (NIOSH) Publication 78-126*.

#### FDA PROPOSES REGULATIONS FOR TWO MICROWAVE DIATHERMY DEVICES

The FDA has issued for public comment two proposed regulations that classify both microwave (MW, 915-2,450 MHz) and shortwave (pulsed or continuous electromagnetic energy from 13 to 27.12 MHz) diathermy devices into class II (performance standards) for use in applying therapeutic deep heat and into class III (premarket approval) for all other uses. The Physical Medical Device Classification Panel has recommended that both MW and shortwave diathermy devices be classified into class II. Class II provides for the future development of one or more performance standards to assure the safety and effectiveness of the device, while class III provides for each manufacturer to submit to FDA a premarket approval application at a date to be set in a future regulation. The Agency believes that performance standards for MW and shortwave diathermy devices are necessary because general controls are insufficient to prevent the risks to health presented by these devices. Performance standards would provide reasonable assurance of the safety and effectiveness of these devices. The FDA believes that sufficient information is available to establish performance standards for both devices, and will issue a final regulation for classifying these devices after considering public comments.

*Fed Regist* 44(168): 50511-50513; 1979.

#### INVENTORS HONORED BY BRH

Mohammed H. Zanboorie, Earl W. Robinson, Albert Van de Griek, Jr., Richard W. Kisielewski, and Gideon Kantor were among the 22 members honored at

the Patent Recognition Ceremony held in October 1979. Mr. Zanboorie's patent for a switch failure monitoring device has been incorporated into microwave ovens as an additional safety feature that renders the oven inoperative if either of the oven's two required safety interlocks fails to operate. E. W. Robinson, A. Van de Griek, Jr., and R. W. Kisielewski were honored for their positive position interlock concealment shutter. This device conceals and prevents intentional or accidental defeat of a safety interlock switch on microwave ovens. G. Kantor was honored for a direct contact microwave diathermy applicator that consists of a rectangular waveguide loaded with two parallel teflon seals. The configuration of the applicator induces an approximately uniform heating pattern over a substantial portion of the treated tissue area and minimizes potentially harmful scatter radiation.

*BRH Bulletin* 13(21): 4-6; 1979.

#### ITEMS FROM THE COMMERCE BUSINESS DAILY

##### ☐ A CRITICAL APPRAISAL OF THE BIOLOGIC EFFECTS OF EXPOSURE TO MICROWAVE AND OTHER RADIO FREQUENCIES.

The Environmental Protection Agency, Headquarters Procurement Operations, Procurement Section C (PM-214-C), Crystal Mall #2, Room 1022A, Washington, DC 20460 is negotiating with the National Academy of Sciences, 2101 Constitution Avenue, Washington, DC 20418 for this study on the critical appraisal of the biologic effects due to exposure to radio frequency waves including microwaves. (October 19, 1979)

## MEETINGS AND CONFERENCES

### INTERNATIONAL RADIATION PROTECTION ASSOCIATION FIFTH CONGRESS

*Date:* March 9-14, 1980  
*Place:* Jerusalem, Israel: Jerusalem Convention Center  
*Sponsor:* Israel Health Physics Society, International Radiation Protection Association (IRPA)  
*Requests for Information:* Israel Health Physics Society, c/o Soreq Nuclear Research Center, Yavne 70600, Israel  
*Content:* Sessions will cover all aspects of protection against ionizing and nonionizing radiation

### 15th ANNUAL MICROWAVE POWER SYMPOSIUM

*Date:* May 6-9, 1980  
*Place:* Ames, IA: University Iowa  
*Sponsor:* International Microwave Power Institute (IMPI)  
*Requests for Information:* Dr. Glen Fanslow, Department of Electrical Engineering, Iowa State University, Ames, IA 50010  
*Content:* Technical sessions and short courses will be presented. Topics will include new technical contributions in noncommunication areas of radio frequency and microwave power such as biomedical applications; biologic effects on humans, animals, and microbiologic systems; chemical and plasma process; combination thermal and microwave food cooking systems; radio frequency and microwaves in the food industry; consumer microwave oven usage patterns; and industrial radio frequency and microwave systems and applications

### 1980 IEEE/MTT-S INTERNATIONAL MICROWAVE SYMPOSIUM

*Date:* May 28-30, 1980  
*Place:* Washington, DC: Shoreham-Americana Hotel  
*Sponsor:* Institute of Electrical and Electronics Engineers (IEEE)--Microwave Theory & Techniques  
*Requests for Information:* B. Shelag, Arrangements Chairman, Naval Research Laboratory, Code 5251, Washington, DC 20375  
*Content:* Topics will cover the expected growth in microwave technology in the 1980s and will include microwave and millimeter wave devices, microwave acoustics, communication systems, field and network theory, and bioeffects.

### THIRD INTERNATIONAL SYMPOSIUM ON CANCER THERAPY BY HYPERTHERMIA, DRUGS, AND RADIATION

*Date:* June 22-26, 1980  
*Place:* Fort Collins, CO: Colorado State University  
*Sponsor:* National Cancer Institute, Colorado American Cancer Society, Journal National Cancer Institute, University of Utah, Colorado State University  
*Requests for Information:* Office of Conferences & Institutes, Rockwell Hall, Colorado State University, Fort Collins, CO 80523

#### *Selected Bibliography of Papers to be Presented:*

HYPERTHERMIA AND ELECTRON AFFINIC COMPOUNDS.  
G. E. Adams

HEAT TRANSFER MECHANISMS AND THERMAL DOSIMETRY.  
H. F. Bowman

APPLICATIONS OF MICROWAVE, ULTRASOUND AND RADIO-FREQUENCY HEATING IN VIVO. J. Hunt

PHYSIOLOGICAL CONSIDERATIONS. C. W. Song

CLINICAL LOCAL HEATING--RF. J. H. Kim

CLINICAL LOCAL HEATING--RF. K. Storm

CLINICAL LOCAL HEATING--MICROWAVES. R. M. Scott

CLINICAL LOCAL HEATING--RF--INTERSTITIAL. M. L. M. Boone, M. Manning

CLINICAL TECHNIQUES AND RESULTS FOR WHOLE BODY HYPERTHERMIA. T. Herman, L. Parks, W. Levin, H. Reinhold

### INTERNATIONAL SYMPOSIUM ON THE BIOLOGIC EFFECTS OF ELECTROMAGNETIC WAVES

*Date:* June 30-July 4, 1980  
*Place:* Near Paris, France: Centre Supérieur d'Enseignement des Affaires (CESA), Near Paris, France  
*Sponsor:* International Union of Radio Science (URSI), Comité National Français de Radioélectricité Scientifique (CNFRS), International Protection Agency, Bioelectromagnetics Society  
*Requests for Information:* M. A. J. Berteaud, CNRS, 2, rue Henry Dunant, 94320 THAIS, France  
*Content:* Topics will include the interactions of electromagnetic fields with biologic systems; the industrial and domestic uses of electromagnetic radiations; dielectric properties of living matter; dosimetry; molecular and cellular effects; physiologic, physiopathologic, and genetic effects; behavioral effects; and medical applications, such as hyperthermia and microwave thermography

## MEETINGS AND CONFERENCES

*Biological Effects of Nonionizing Electromagnetic Radiation IV(3), March 1980*

### BIOELECTROMAGNETICS SOCIETY SECOND ANNUAL MEETING

*Date:* September 14-18, 1980  
*Place:* San Antonio, TX: El Tropicano Hotel  
*Sponsor:* Bioelectromagnetics Society  
*Requests for Information:* Bioelectromagnetics Society, P.O. Box 3651, Arlington, VA 22203  
*Content:* Topics will cover the interaction of electromagnetic energy and acoustic energy with biologic systems, including behavioral, physiologic, neurologic, endocrine, developmental, genetic, and cellular and ultrastructural effects. Also included are the dielectric properties of biologic materials, electric field effects, exposure systems, dosimetry, diagnostic and therapeutic applications, interactive mechanisms, instrumentation, hyperthermia, and field perturbations

### FIFTH INTERNATIONAL WROCLAW SYMPOSIUM ON ELECTROMAGNETIC COMPATIBILITY

*Date:* September 17-19, 1980  
*Place:* Wroclaw, Poland: Wroclaw Technical Univ.  
*Sponsor:* Association of Polish Engineers, Wroclaw Technical Univ., Inst. of Telecommunications, Polish Acad. of Sciences, International Union of Radioscience (URSI), International Electrotechnical Commission (IEC)  
*Requests for Information:* W. Moron, Symposium Secretary General, EMC Symposium, 51-645 Wroclaw 12, Poland.  
*Content:* All aspects of electromagnetic compatibility will be covered. Specific topics will include immunity and susceptibility; national and international cooperation in establishing regulations, limits, standards, and specifications; harmful effects of radio frequency energy; and shielding and filtering

### FIFTH INTERNATIONAL CONFERENCE ON INFRARED AND MILLIMETER WAVES

*Date:* December 8-12, 1980  
*Place:* Wurzburg, West Germany  
*Sponsor:* Institute of Electrical and Electronics Engineers (IEEE)--Microwave Theory & Techniques Society  
*Requests for Information:* K. J. Button, MIT National Magnetic Laboratory, Cambridge, MA 02139

*Content:* Sessions will cover the biologic effects of electromagnetic radiation

### FOURTH INTERNATIONAL ELECTROMAGNETIC COMPATIBILITY SYMPOSIUM

*Date:* March 10-12, 1981  
*Place:* Zurich, Switzerland: Federal Institute of Technology  
*Sponsor:* Association of Swiss Electrotechnicians  
*Requests for Information:* Dr. T. Dvorak, ETH Zentrum-KT, 8092 Zurich, Switzerland  
*Content:* Topics will cover the protection of the electromagnetic environment and will include the social and economical impact of electromagnetic compatibility (EMC); electromagnetic pollution, control, and enforcement; national and international cooperation in EMC; immunity of electronic systems; EMC of communications, electric power, and automation; EMC hazards to vital safety systems; compatibility of medical electronics; biologic effects of radio frequency energy; and shieldings and absorptive materials

### TENTH L. H. GRAY CONFERENCE

*Date:* July 13-16, 1981  
*Place:* Oxford, England  
*Sponsor:* Institute of Cancer Research  
*Requests for Information:* Dr. R. C. Hill, Institute of Cancer Research, Royal Marsden Hospital, Sutton, Surrey, England  
*Content:* The biology and biophysics of radio frequency, microwave, and ultrasonic radiation will be reviewed, particularly with respect to their potential therapeutic value

### 20th GENERAL ASSEMBLY OF THE URSI

*Date:* August 10-19, 1981  
*Place:* Washington, DC: Hyatt Regency Hotel  
*Sponsor:* International Union of Radio Science (URSI)  
*Requests for Information:* Executive Secretary, R. Y. Dow, National Academy of Sciences, 2101 Constitution Ave., N.W., Washington, DC 20418 or (202) 389-6478

## CURRENT RESEARCH

**0553 MECHANISMS OF MICROWAVE NEURAL INTER-ACTION.** Durney, C. H. (Dept. Electrical Engineering, Sch. Engineering, Univ. Utah, Utah Higher Education System, 1400 E. 2nd St., Salt Lake City, UT 84112).

Research is being conducted to explore the mechanisms that cause responses to low-level microwaves in neural substrates and to study the interactive mechanisms that are operative when electromagnetic fields (EMF) come in contact with critical nerve substrates. The first part of the study will be concerned with nerve terminal stimulation and transmitter release. Synaptosomes (pinched-off pre-synaptic terminals of neurons) will be isolated from whole rat brain. Horseradish peroxidase will be used as a tracer to determine if the EMF causes damage. The second part of the study will involve the effects of EMF on receptor binding molecules for several neural transmitters. (funding period n/a)

Supporting Agency: U.S. Dept. Defense: Navy, Office Naval Res.

**0554 BIOLOGICAL EFFECTS OF MICROWAVE RADIATION (RABBITS).** Eisenbud, M. (Dept. Environmental Medicine, Sch. Medicine, New York Univ., 550 1st Ave., New York, NY 10016).

This project is part of a broader program to study adverse health effects (from acute to chronic) from environmental factors, such as microwaves. The general objectives of the research are to define the nature and extent of such effects with the aim of instituting appropriate preventive or control procedures. The research includes: laboratory studies on the biochemical mode of action of environmental toxicants, exploratory studies aimed at improving the reliability and efficiency of predictive toxicologic tests, improvement of diagnostic procedures for diseases possibly related to environmental factors, epidemiologic investigations, and field studies on the distribution of pollutants. (funding period 1/77-12/79).

Supporting Agency: HEW, PHS, NIH, Natl. Inst. Environmental Health Sciences

**0555 EFFECTS OF ELECTROMAGNETIC ENERGY ON THE IMMUNE SYSTEM OF ANIMALS.** Cain, C. A.; Tompkins, W. (Dept. Electrical Engineering, Sch. Engineering, 207 Engineering Hall, Univ. Illinois, Urbana Champaign Campus, Urbana, IL 61801).

The effects of electromagnetic (EM) fields on the immune response in mammals will be investigated and quantitative relationships between threshold and suprathreshold exposure parameters and observed immunologic alterations will be determined. Young adult hamsters (8-10 wk old) will be infected intraperitoneally with vaccinia virus. The infected animals will either be exposed to EM fields,

sham exposed, or will serve as neutral controls. Serum from infected animals will be collected by cardiac puncture at 7- to 10-day intervals after the injection. The serum will be analyzed to determine antivaccinia antibodies by vaccinia neutralization, antibody-dependent cell-mediated immune responses (using spleen lymphocytes), macrophage immunity, and lymphocyte killer cell immune mechanisms. (funding period 0/79-n/a)

Supporting Agency: U.S. Dept. Defense: Navy, Office Naval Res.

**0556 RADIO FREQUENCY/MICROWAVE TERATOGENIC EFFECTS STUDY.** Conover, D. (Div. Bio-medical and Behavioral Science, HEW, PHS, Center for Disease Control, NIOSH, 4676 Columbia Pkwy., Cincinnati, OH 45226).

A follow-up study will be initiated to determine the thermal threshold for production of teratogenic effects in rats. Groups of pregnant rats will receive continuous high-intensity whole-body 27.12-MHz radio frequency (RF) radiation on the gestation day when maximal teratogenic effects are induced, and exposures will be discontinued as the animals reach a preselected temperature of 39, 40, 41, 42, or 43 C. In a second study, pregnant rats will be irradiated on the same gestation day for longer periods of time at lower power levels to assess the influence of irradiation time on the acute thermal threshold level. A total power absorption analyzer is being developed that will be used in conjunction with the NIOSH RF Near-Field Synthesizer to perform bioeffects research from 10 to 100 MHz. The analyzer will be used to noninvasively determine the absorbed RF power to aid in extrapolating the results of animal bioeffects studies to humans. Extrapolation of the results of animal bioeffects studies to humans will be useful in setting maximum permissible personnel RF/microwave exposure levels. (funding period 10/76-9/80)

Supporting Agency: HEW, PHS, Center Disease Control, NIOSH

**0557 INVESTIGATION OF THE FACTORS DETERMINING MICROWAVE ABSORPTION IN NORMAL AND MALIGNANT TISSUE.** Grant, E. H.; Sheppard, R. J.; Szwarnowski, S. A. (Dept. Physics, Queen Elizabeth Coll., Univ. London, Campden Hill Rd., London W8 7AH, England).

Methods of optimizing the absorption of microwave energy by malignant tissue to achieve differential heating are being devised. Thus, the project involves both the development of methods of launching microwaves into a tumor and the measurement of the dielectric properties of normal and malignant tissue to determine a frequency region where microwave radiation is absorbed differentially by malignant cells at the expense of normal cells. The microwaves will be propagated into the tissue using a probe or appli-

## CURRENT RESEARCH

Biological Effects of Nonionizing Electromagnetic Radiation IV(3), March 1980

cator with a small diameter coaxial line mounted in a hypodermic needle. Matching experiments will be carried out using bolus material and measurements of standing wave ratio will be made for various sized applicators. Measurements of the electric properties of normal and malignant tissue will be made with a Time Domain Spectrometer (TDS) as well as by the more conventional frequency domain techniques. The electric permittivity and conductivity of solid tissue and cell suspensions over a frequency range of 1 MHz-100 GHz will be determined, and the results will be interpreted in terms of the quantity and nature of the free water and water of hydration that are present. If the study verifies current evidence that suggests that the water structure is different for normal and malignant tissue, then the identification of a frequency region where cancer cells absorb more radiowave or microwave energy than normal cells will be attempted. Thus far a microwave probe has been devised and tested on tumor-bearing mice; good localization of heat in the tumor has been achieved. TDS methods specifically suited to the determination of the permittivity and conductivity of very lossy materials have been designed and tested. (funding period 19/77-9/82)

Supporting Agency: Cancer Res. Campaign (England)

0558 MICROWAVE EFFECTS ON CNS. Albert, E. N. (Dept. Anatomy, Sch. Medicine & Health Sciences, George Washington Univ., 2121 Eye St. N.W., Washington, DC 20037).

The effects of both acute and chronic exposure of microwave frequencies common for Navy equipment on the central nervous system of Chinese hamsters and other small rodents will be investigated. The animals will be exposed to low power density microwave fields for 1 hr-60 days, and the histopathologic effects and alterations of the blood-brain barrier will be emphasized. Special neurocytologic stains for determining degenerating axons, terminal boutons, dendritic spines, myelin, general cytoplasmic appearance, and gliosis will be used to study the results. In addition, the subcellular aspects of neurons and glia will be examined by electron microscopy, and labeled amino acids, ions, and protein transport across the blood-brain barrier will be studied by autoradiography. Thresholds for observed effects will be determined in terms of both exposure intensity and exposure duration. (funding period 5/78-n/a)

Supporting Agency: U.S. Dept. Defense: Navy, Office Naval Res.

0559 ACCELERATION OF FRACTURE HEALING BY ELECTRICAL FIELDS. Brighton, C. T.; Friedenberg, Z. B.; Black, J.; Jimenez, S.; Pollack, S.; Steinberg, M.; Heppenstall, R. B. (Dept. Orthopedic Surgery, Sch. Medicine, Univ. Pennsylvania, 36th and Hamilton Walk, Philadelphia, PA 19104).

See Current Research 0473 for description of this research. (funding period 3/78-7/80)

Supporting Agency: HEW, PHS, NIH, Natl. Inst. Arthritis, Metabolism, & Digestive Diseases

0560 MORTALITY, REPRODUCTIVE AND INDUSTRIAL HYGIENE STUDY OF WORKERS EXPOSED TO MV-RF ENERGY. Egan, B.; Cox, C.; Meinhardt, T. (Div. Surveillance Hazard Evaluations and Field Studies, HEW, PHS, Center Disease Control, NIOSH, 4676 Columbia Pkwy., Cincinnati, OH 45226).

See Current Research 0472 for description of this research. (funding period 10/77-9/81)

Supporting Agency: HEW, PHS, Center Disease Control, NIOSH

0561 DNA DAMAGE/REPAIR BY ENVIRONMENTAL CARCINOGENS/MUTAGENS. Hascitine, W. A.; Martin, R. F.; Simon, M.; Royer-Pokora, E.; Williams, B.; Gordon, L. (Sidney Farber Cancer Inst., Inc., 44 Binney St., Boston, MA 02115).

Mechanisms whereby deoxyribonucleic acid (DNA) lesions created by environmental agents, such as microwaves, are fixed into genetic lesions will be investigated. The study will include the identification of new enzymatic repair activities and the site of DNA sequence and an analysis of the relative frequencies of the different types of damage and of the effect of purified DNA repair enzymes on a variety of DNA lesions. In addition, specific enzyme defects in cells derived from patients with genetic defects that involve faulty DNA repair (such as xeroderma pigmentosum, ataxia telangiectasia, retinoblastoma, Fanconi anemia, and Hutchinson-Gilford progeria) will be analyzed. Enzymes will be purified from bacteria and eukaryotes, and DNA templates of defined sequence that have been modified by environmental agents will be used as substrates for DNA and ribonucleic acid polymerases and endo- and exonucleases. Protein purification procedures will be applied to characterize the enzymes involved. (funding period 1/79-12/80)

Supporting Agency: HEW, PHS, NIH, NCI

0562 COLLABORATION ON AN IMPLANTABLE RF STIMULATOR. Ko, W. H. (Case Western Reserve Univ., Case Inst. Technology, 2040 Adelbert Rd., Cleveland, OH 44106).

An implantable radio frequency stimulator will be developed. This project is part of a broader program to develop a Biomedical Electronics Resource Center to service the national community in microelectronics and instrumentation. The Resource Center, located in the Engineering Design Center of

Case Western Reserve University, provides additional equipment to update the existing research facilities in microelectronics and integrated circuits, medical instrumentation, and mechanical design to provide service, training, and research in biomedical electronics. The major groups in the Resource are: a Microelectronics Technology Laboratory for implant instruments, medical transducers, and solid state electronics technology; a Medical Instrumentation Laboratory for research prototype design and development of practical health care instruments; a Package and Quality Assurance Laboratory to establish and operate facilities for packaging medical instruments and perform final testing of devices and instruments; and an Education and Training Group to interface with associated medical research groups to disseminate the information to other research institutions and industrial organizations. The research results, design service, and training opportunities will be provided by the Resource to the local and national biomedical community. (funding period 12/77-11/79)

Supporting Agency:HEW, PHS, NIH, Div. Res. Resources

0563 EFFECTS OF MICROWAVES ON NEUROENDOCRINE FUNCTION. Lu, S.; Michaelson, S. M. (Dept. Radiation Biology and Biophysics, Sch. Medicine & Dentistry, Univ. Rochester, 601 Elmwood Ave., Rochester, NY 14627).

Research to examine and delineate physiologic regulations (neuroendocrine function) and tissue injuries (serum enzymes) in microwave exposed rats free of nonspecific stresses will be conducted. The quantitative relation among power densities, body temperatures, and neuroendocrine functions or tissue injuries will be assessed. Specific attention will be paid to the interrelation of hypothalamic-hypophyseal/thyroid/adrenal somatotropic axes in microwave exposed animals. The interaction of previous exposure on responses or injuries of rats to subsequent exposure will also be investigated. Recovery or manifestation of acute neuroendocrine perturbances or tissue injuries by microwave exposure will be attempted. Rats will be acclimated to experimental procedures; a 3-hr equilibrium period will be given before each microwave exposure. The proposed project will extend from single to repeated (60 times, 4 hr/day) exposure to 2,450 MHz continuous wave microwaves in the far-field at 0.1-40 mW/cm<sup>2</sup> or the equivalent specific absorption rate. The absorption rate will be determined for an interspecies and interlaboratory rate. The exposure techniques (single- versus multi-body) will be compared. (funding period 8/79-7/80)

Supporting Agency:HEW, PHS, NIH, Natl. Inst. Environmental Health Sciences

0564 SUPPORT FOR STUDIES OF BIOMEDICAL SCIENCES. Miskimen, G. W.; delCastillo, J.; Roman, J.; Sahai, H.; Herndon, A.; Arbona, J.; Jao,

T.; Rudzinski, W. (Dept. Biology, Sch. Arts and Sciences, Univ. Puerto Rico, Mayaguez Campus, PR 00708).

To further develop and stimulate biomedical research and training among faculty members at the University of Puerto Rico, five new projects are proposed. One of the projects will involve the study of microwave exposure spectroscopy of effects on microorganisms, comparison of normal and abnormal tissue, and study of cell membrane features. (funding period 9/77-2/80)

Supporting Agency:HEW, PHS, NIH, Div. Res. Resources

0565 ENVIRONMENTAL INTERACTIONS WITH THE AGING PROCESS. Sacher, G. A. (Div. Biological and Medical Res., U.S. Dept. Energy, 9700 S. Cass Ave., Argonne, IL 60439).

The effects of environmental pollutants, such as high-voltage electric fields, on the daily (diel) cycles of energy metabolism, motor activity, and body temperature will be studied in small rodents. The initial phase of work with pollutants will be focused on radiation variables including both ionizing and nonionizing; the nonionizing radiation will include 60-Hz electric fields and 2,450-MHz microwaves (as produced by the proposed Solar Power Satellite system). The effects of each pollutant will be characterized and then analyzed to determine whether subsequent health effects can be predicted. Diel cycles of metabolism, activity, and temperature will be logged continuously and automatically for several mice simultaneously for periods up to 2 weeks. The search for indicator-variables has been limited to energy expenditure variables; thus far, three variables have been identified that predict the length of life, i.e., resting metabolic rate (negative correlation), ratio of average to resting metabolic rate (positive correlation), and change of metabolic rate from youth to old age (negative correlation). The search will now be extended to the activity and temperature variables, which have become functional only recently. (funding period 0/79-n/a)

Supporting Agency:U.S. Dept. Energy, Office Health & Environmental Res.

0566 HUMAN RESPONSES TO THE THERMAL ENVIRONMENT. Stolwijk, J. A. (Pierce Lab., John B. Pierce Foundation Connecticut, 290 Congress Ave., New Haven, CT 06519).

As part of a research program to investigate human responses to the thermal environment, the thermal and nonthermal effects of microwaves will be studied in nonhuman primates using a combination of physiologic and behavior techniques. Objectives of this program include a better understanding of the effects of the thermal environment, identification of vulnerable segments of the population,

## CURRENT RESEARCH

*Biological Effects of Nonionizing Electromagnetic Radiation IV(3), March 1980*

and the development of strategies for effective protection of such vulnerable individuals and for evaluation of public health consequences of energy conservation strategies. (funding period 6/77-5/80)

Supporting Agency:HEW, PHS, NIH, Natl. Inst. Environmental Health Sciences

**0567 BIOPSYCHOLOGICAL STUDIES OF MICROWAVE IRRADIATION.** Justesen, D. R.; Levinson, D. M.; Chernovetz, M. E.; Woire, V. B. (Dept. Psychiatry, Medical Center, Sch. Medicine, Univ. Kansas, 39th St. and Rainbow Blvd., Kansas City, KS 66103).

Data collected to date from a 3-yr study of longevity of mice that were exposed in utero to near-lethal doses of 2,450-MHz microwave radiation demonstrated an increased mortality among control and radiated animals. Spontaneous tumors appeared in two controls ( $n = 81$ ) but not in radiated mice ( $n = 83$ ). The acute studies focused on distributions of thermalized energy in the brain and lower body of anesthetized rats, guinea pigs, and rabbits during brief, but near-lethal, exposures in a 2,450-MHz multipath field. Pre-exposure temperatures within an animal differed anatomically by 0.5-1 K (e.g., colon versus superficial cortex); radiation-induced whole-body  $\Delta T$ s of 4.5-12 K were associated with altered distributions that differ both anatomically and among species. Continuing studies of escape behavior by rats in intense 918-MHz multipath fields confirmed that irradiation per se, even at levels that prove lethal within minutes, lacked the sensory salience to promote escape learning; however, pairing of photic (and to a lesser extent, acoustic) stimuli as sensory cues with irradiation can reinforce successful escape. Twelve pilot studies have been completed to determine optimal conditions for adjuvant treatment by microwave hyperthermia of experimentally induced glioblastoma in rats. Formal studies will begin this year. Complementing the work on glioblastoma is recent pilot work on the role of fever in transfer of circulating antibody across the

cerebrospinal-fluid (CSF) barrier. There is no evidence in rats that subconvulsive, microwave-induced fevers of short duration (<30 min) provide access to CSF (i.e., to the brain) by experimentally induced antibody. The peak titer of serum antibody (in response to pneumococcal antigen) is variably suppressed or augmented by the febrile treatments, but the evidence is not statistically significant. (funding period 9/77-8/80)

Supporting Agency:HEW, PHS, FDA, BRH

**0568 INTERACTION OF DNA DOUBLE HELIX WITH E. M. FIELDS.** Prohofsky, E. W. (Dept. Physics, Sch. Science, Purdue Univ., Executive Bldg., West Lafayette, IN 47907).

The absorption of several duplex deoxyribonucleic acid homopolymers in the microwave frequency region will be calculated. The calculations will be rigid ion calculations based on calculated eigenvectors, and will be made for various helix lengths and for kinked or bent helices. (funding period 9/78-8/80)

Supporting Agency:HEW, PHS, FDA

**0569 SMALL DROPS IN ELECTROMAGNETIC FIELDS.** Morrison, C. A. (Electronics Res. and Development Command, Harry Diamond Lab., U.S. Dept. Defense, Army, 2800 Powder Mill Rd., Adelphi, MD 20783).

The theoretical effect of electromagnetic fields on the dynamic properties of small drops will be investigated. Rayleigh's theory of small drops oscillations will be extended to include the effect of electromagnetic fields on the dynamic properties of dielectric and charged conducting spheres. (funding period 3/79-n/a)

Supporting Agency:U.S. Dept. Defense: Army, Electronics Res. & Development Command



## CURRENT LITERATURE

- 6388      ORIENTATION OF ANIMALS IN SPACE AND TIME.  
(Ger.) Lindauer, M. (Zoologisches Institut, Universität Würzburg, D-8700 Würzburg, W. Germany). *Rev Physiol Biochem Pharmacol* 85: 1-62; 1979. (133 refs)

Studies on the optical, chemical, and mechanical orientation of animals in space and time are reviewed. Previous experiments have demonstrated that the orientation system of electric fish is based on the emission of electric impulses (0.1-4 msec) by the electric organ that produces an electric field around the body. The disturbance of this field by any object having an electric conductivity different from that of water is perceived by specific receptors. These receptors are sensitive to changes in potential of as little as 0.03  $\mu\text{V}/\text{cm}$ . Birds, insects, and bees are sensitive to changes in the earth's magnetic field and can use its variation for orientation. Other studies have demonstrated that these animals may be disoriented in shielded space or in an artificial magnetic field. In the honey bee, the direction of the axis of the waggle dance, communicating the direction in which to find the food, is consistently misdirected by the earth's magnetic field. The degree of misdirection correlates highly with the daily variation in the total intensity of the earth's magnetic field. In the absence of other timers, the daily variations in the magnetic field are used by the honey bee as an external clock.

- 6389      PIGEONS HAVE MAGNETS. (Eng.) Walcott, C. (Dept. Biology, State Univ. New York at Stony Brook, Stony Brook, NY 11794); Gould, J. L.; Kirschvink, J. L. *Science* 205(4410): 1027-1029; 1979. (19 refs)

Evidence is presented to show that the ability of pigeons to sense magnetic fields may be associated with a small, unilateral structure between the brain and the skull that contains magnetite in what appears to be single domains (tiny unit magnets). Tests for stable and superparamagnetic domains in pigeons were performed with a SQUID magnetometer after about 24 fresh, previously frozen, or perfused pigeon heads and necks were dissected. Permanently magnetic material was found in each of the pigeon specimens tested. The material was unilateral and was located either in a small (1 x 2 mm) piece of tissue between the dura and the skull or was too closely associated with the skull to be separated from it conveniently. About 40% of the pigeons had a natural remanence (a net field due to a preferential direction of alignment among the many individual magnets) that ranged from  $10^{-7}$  to  $10^{-6}$  electromagnetic units. All pigeons had an inducible remanence (a measure of the total amount of magnetic material) of  $10^{-6}$  to  $10^{-5}$  electromagnetic units. The relatively weaker natural remanence and other observations suggest that the alignment among the single-domain magnets is only locally regular. Few, if any, superparamagnetic domains were found. Light and electron microscopy of the naturally magnetic tissue revealed that it is richly supplied with clusters of electron-

opaque structures approximately 0.08-0.15  $\mu\text{m}$  long and with an approximate length-to-width ratio of 4:1. Electron probe analysis revealed that these particles are rich in iron. Additional microscopic observations and measurements of Curie temperature led to the conclusion that the primary magnetic component is magnetite.

- 6390      INFLUENCE OF THE EARTH'S MAGNETIC FIELD ON THE COMB BUILDING ORIENTATION OF HORNETS. (Eng.) Kisliuk, M. (Dept. Electronics, Sch. Engineering, Tel Aviv Univ., Ramat-Aviv, Israel); Ishay, J. S. *Experientia* 35(8): 1041-1042; 1979. (5 refs)

To investigate the influence of the earth's magnetic field on comb-building orientation, hornet workers (*Vespa orientalis*) maintained in artificial breeding boxes in groups of 10-20 individuals were placed both inside a solenoid and at some distance from it in the same room. Experiments were conducted with adult worker hornets more than 1-day-old and with juvenile hornets. The maximum current in the solenoid's coil was 37.2 mA (inverted natural field). The introduction of a magnetic field that counteracted the vertical component of the earth's field, thereby creating a zero field, resulted in complete disorientation of both adult and juvenile hornets. The mortality rates for adults and juveniles in this zero field were 25% and 70-90%, respectively. Adult hornets built cells or even small combs in which they deposited eggs, whereas juvenile hornets showed almost no building activity. Neither adult nor juvenile hornets placed in pulsed fields (0.5 sec pulse duration) averaged to zero showed any building activity; however, the mortality of adults and juveniles in this zero pulsed field was only 10-15%. Hornets placed inside an inverted magnetic field needed 2-3 days to adapt but then proceeded to develop and build in a normal manner. Hornets placed in pulsed fields (0.5 sec pulse duration) averaged to 50% of the natural field built regular combs, albeit with cells almost twice the natural size, but their mortality rate was relatively high (20-65%). During zero field conditions, only two combs were observed; one attached to the ceiling with two uncompleted cells and one attached to a wall with two cells oriented at 40-50 degrees from vertical. Both pedicles had an elliptical cross-section with the larger axis oriented in the north-south direction, as opposed to the circular cross-section of normal pedicles. The following additional phenomena were observed in two breeding boxes placed at both ends of the solenoid where the axial field of the solenoid was not uniform: simultaneous building of combs on the ceiling and on the side walls; combs with cells of different sizes; and cell walls containing considerably more strips of cellulose than cell walls in control boxes. The above results suggest that the terrestrial magnetic field is the main guideline for vespan building orientation.

- 6391      MICROWAVES CAN KILL INSECT PESTS. (Eng.) Hurlock, E. T. (Agricultural Science

Service, Ministry Agriculture, Fisheries and Food, U.K.); Llewelling, B. E.; Stables, L. M. *Food Manuf* 54(8): 37, 39; 1979. (4 refs)

Semicommercial scale experiments on the use of microwaves for disinfecting dry food materials are described. The experimental set-up consisted of a tunnel approximately 8 m long of rectangular cross-section measuring 152 x 228 cm, through which a variable-speed moving belt passed. An 896-MHz generator produced a microwave beam that was made to traverse the belt a number of times over a distance of 3 m before being absorbed in a tank of water. The infested materials were passed through the tunnel in polythene bags on the moving belt. Test insects were counted and placed in the bags with 200 g of a food material. A series of tests was run with a variety of exposure times and power settings. After 1 wk of exposure, the food was removed from the bags and the insects were counted. In one test conducted with bags of wheat (13.7% moisture content), a microwave dose of 780 kW-sec resulted in 100% mortality rates for three major beetle pests (*Oryzaephilus surinamensis*, *Tribolium castaneum*, and *Sitophilus granarius*). In another test with cocoa crumbs (18% moisture), a microwave dose of 599 kW-sec resulted in 90% mortality for *T. castaneum* adults and 96% mortality for *Ephestia cautella* larvae. In a third test with cocoa beans (6% moisture), a microwave dose of 800 kW-sec resulted in 80% mortality for *E. cautella* larvae but only a 29% mortality for *T. castaneum* adults. However, when this test was repeated using hot dry air (85 C) in addition to microwave irradiation, a microwave dose of 780 kW-sec resulted in 100% mortalities for both these pests.

6392 A MICROWAVE SYNDROME? (Eng.) Manna, R. Z. (No affiliation given). *Bell Teleph Mag* 58(4): 24-27, 29, 41; 1979. (0 refs)

The Bell System's microwave radiation facilities are discussed in relation to growing public concern about the possible hazards of exposure to microwave radiation. The Bell System has nearly 5,000 microwave radio installations in the United States; these carry nearly 70% of all long distance phone calls as well as network television programs and data communications. Based on the opinions of experts in this field, Bell officials do not consider exposure levels associated with their equipment to be hazardous either to their employees or to the public. Measured microwave levels around Bell towers in areas to which the public has access indicate that even the stringent Soviet standards for public exposure are met. In terms of occupational exposure, microwave levels, e.g., directly in front of an antenna, are almost always below the 10-mW/cm<sup>2</sup> occupational exposure standard in the United States. It is also pointed out that natural microwave radiation emission from the human body is greater than the exposure resulting from the operation of a microwave relay tower.

6393 MICROWAVE: BASIC BACKGROUND AND TERMINOLOGY. (Eng.) Anonymous. (No af-

filiation given). *Bell Teleph Mag* 58(4): 28; 1979. (0 refs)

A review of microwave technology and its reported effects on humans is presented, with particular reference to the Bell Telephone System's use of this technology in its intercommunications network. There is substantial scientific evidence that microwave levels above 100 mW/cm<sup>2</sup> can harm the human organism as a result of the tissue heating effect; however, levels below 10 mW/cm<sup>2</sup> are not harmful. Some Eastern European countries and the Soviet Union have reported non-heating effects (e.g., headaches, insomnia, fatigue, depression, memory loss) at levels between 10 and 100  $\mu$ W/cm<sup>2</sup>; however, it has not been clearly established whether these effects were caused by microwave radiation.

6394 INTERNATIONAL COLLABORATION ON THE HEALTH EFFECTS OF NONIONIZING RADIATION. (Eng.) Suess, M. J. (WHO Regional Office for Europe 8, Scherfigsvej, 2100 Copenhagen, Denmark). *J Microwave Power* 14(2): 93-94; 1979. (0 refs)

The development of international collaboration on the health effects of nonionizing radiation (NIR) is reviewed. The convening of a working group on NIR by the WHO Regional Office for Europe at the Hague in November 1971 can be considered as the beginning of international activities on NIR protection. This working group developed a sectoral program on NIR protection designed to facilitate relevant investigations, data evaluation and exchange, establishment of biologic criteria for damage, promotion of protective legislation, and training of national surveillance personnel. WHO, together with the United States Department of HEW and the Polish Scientific Council to the Minister of Health and Social Welfare, subsequently sponsored an International Symposium on the Biologic Effects and Health Hazards from Microwave Radiation. The proceedings included presentations on thermal and biologic effects, influences on the nervous system and behavior, effects at the cellular and molecular level, measurements of radiation, and occupational exposure and public health aspects. Working groups were established to critically review and evaluate documents on the health aspects of NIR. Their results, consolidated in a manual for future publication, cover the electromagnetic spectrum of NIR from UV through visible light, infrared, microwave and radio frequency radiation to magnetic and electric fields at power frequencies. Ultrasound radiation is also included in the manual because of its similar applications in medicine, science, and technology. Regulation and enforcement procedures, two directories on national legislation and institutes concerned with NIR, and a glossary of terms are included in the manual.

6395 SOVIET-AMERICAN COOPERATION IN ENVIRONMENTAL HEALTH SCIENCE. (Eng.) Schambra, P. E. (Nat'l. Inst. Environmental Health Sciences, P.O. Box 12233, Research Triangle Park, NC 27709); Rall, D. P.; Sidorenko, G. I.; Pinigin, M. A.; Lit-

vinov, N. N. *Environ Health Perspect* 30: 1-7; 1979. (40 refs)

The first 5 yr of experience with a Soviet-American collaborative program in the environmental health sciences is reviewed. Beginning in 1975, 3 yr after its initiation, the program was expanded to include studies on the biologic effects of physical factors in the environment. These studies have focused on the biologic effects of nonionizing radiation, particularly the effects of microwave radiation and static and low frequency electromagnetic fields. Joint efforts have been initially aimed at revealing the potential health hazards associated with long-term exposures to low doses of microwaves. During the 1st yr of the program, the Soviet side reported effects on rabbits and rats due to microwave exposure at power densities of 10-500  $\mu\text{W}/\text{cm}^2$  and exposure durations of 7 hr/day, 5 days/wk for 3 mo. Changes in the electroencephalograms of rabbits were measured along with alterations in behavior and immunologic and cytochemical parameters in the blood of rats. The American studies, which have been performed at higher exposure levels, have generally shown no effects unless the microwave levels were high enough to produce heating of the specimens. However, exceptions to these findings include increased calcium efflux from brain tissue at microwave fields modulated near brain wave frequencies, suppression of immunologic responses in rabbits exposed to 10  $\text{mW}/\text{cm}^2$  for a 6-mo period, and decreased performance in rats following exposures to 15  $\text{mW}/\text{cm}^2$  and above. Collaboration on studying the effects of static and low frequency electromagnetic fields is in the early stages of development. An exchange of reviews of national scientific literature on this topic has taken place, and a joint workshop has been convened to propose joint work on outstanding problems. The first edition of a bilingual glossary of specialized scientific terms used by both countries in the area of environmental health was completed in 1975.

6396 EFFECTS OF NONIONIZING RADIATION ON THE CENTRAL NERVOUS SYSTEM, BEHAVIOR, AND BLOOD: A PROGRESS REPORT. (Eng.) McRee, D. I. (Natl. Inst. Environmental Health Sciences, P.O. Box 12233, Research Triangle Park, NC 27709); Elder, J. A.; Gage, M. I.; Reiter, L. W.; Rosenstein, L. S.; Shore, M. L.; Galloway, W. D.; Adey, W. R.; Guy, A. W. *Environ Health Perspect* 30: 123-131; 1979. (4 refs)

The effects of nonionizing electromagnetic radiation on the central nervous system, behavior, and blood are reviewed in light of recent research conducted in the United States as part of a collaborative effort with the Soviet Union. Results of investigations studying the effects of microwaves on isolated nerves, synaptic function, transmission of neural impulses, electroencephalographic (EEG) recordings, behavior, and the chemical, cytochemical, and immunologic properties of the blood are reported. Increased calcium efflux from isolated forebrains was observed when neonatal chick brains were exposed to 6-Hz amplitude-

modulated 147-MHz fields at power densities of 1-2  $\text{mW}/\text{cm}^2$ . Cats have also been exposed to 147-MHz fields amplitude-modulated at brain wave frequencies (power density, 1  $\text{mW}/\text{cm}^2$ ), and such fields had a strong influence on spontaneous and conditioned EEG patterns. Evidence that microwave irradiation may weakly enhance synaptic transmission in the spinal cord was obtained when the spinal cords of cats were directly exposed to 2,450-MHz continuous wave radiation for 30 min. Experiments in which adult rats were exposed to 2,450-MHz radiation over a wide power density range indicated that such exposure can produce alterations in learning behavior of animals; decreased performance occurred in direct relation to increases in the power density of exposure. Experiments designed to determine the pathologic, hematologic, and immunologic effects of chronic microwave exposure (2,450 MHz, 10  $\text{mW}/\text{cm}^2$ , 23 hr/day for 6 mo) in rabbits revealed abnormal myeloid/erythroid ratios in the bone marrow of exposed animals compared with controls. This exposure also appeared to slightly suppress immune competence as shown by tests in which pokeweed mitogen was used to stimulate lymphoid cells from the spleens of exposed animals.

6397 A PUBLIC HEALTH APPROACH TO MICROWAVE AND RADIOFREQUENCY RADIATION. (Eng.) Solon, L. R. (Bureau for Radiation Control, New York City Health Dept., New York, NY). *Bull At Sci* 35(8): 51-55; 1979. (12 refs)

A public health approach to setting standards for exposure to microwave (MW) and other radio frequency (RF) radiations in the 30-kHz to 300-GHz frequency range is presented based on a review of experimental, clinical, and epidemiologic studies. Biologic effects of MW and RF observed in animals include the following: chromosomal anomalies in the Chinese hamster and fruit fly (5-40 MHz pulsed, power density not reported); mutagenesis in Swiss male mice (17 GHz at 50  $\text{mW}/\text{cm}^2$ ); changes in cell structure and density of bacteria (50-90 GHz at 10-50  $\text{mW}/\text{cm}^2$ ); teratogenesis in mealworms (9-10 GHz at total power of 20-80 mW) and in mice (2,450 MHz, energy absorption of 3-8 calories/g); behavioral impairment in rats (1.3-1.5 GHz pulsed at 0.4-2.8  $\text{mW}/\text{cm}^2$ ); neuroendocrine and hormonal alterations in rats and dogs (2,450 MHz at 20-60  $\text{mW}/\text{cm}^2$  for 30-60 min); prenatal impairment of body and brain weight in rats (2,450 MHz at 10  $\text{mW}/\text{cm}^2$  for 5 hr/day over 17-day gestation period); blood-brain barrier alterations in hamsters (2,450 MHz at 10  $\text{mW}/\text{cm}^2$ ); central nervous system influence in chicks (147 MHz at 1-2  $\text{mW}/\text{cm}^2$ ); and mortality in rats, rabbits, and dogs (40  $\text{mW}/\text{cm}^2$  for minutes to hours, 2,800 MHz pulsed, various wavelengths between 1 mm and 10 cm). Biologic effects of MW and RF observed in humans (exposure parameters not reported in most cases) include cataractogenesis and other ocular effects, central nervous system influences, speculative oncogenesis (epidemiologic suggestion of carcinogenesis in North Karelia region of Finland but no direct clinical evidence), biochemical imbalances, subjective psychologic complaints (0.01-10  $\text{mW}/\text{cm}^2$ ), and hematologic changes. Based on the available evidence, it is concluded

## CURRENT LITERATURE

Biological Effects of Nonionizing Electromagnetic Radiation IV(3), March 1980

that a permissible occupational exposure level to MW and RF radiation of 500  $\mu\text{W}/\text{cm}^2$  is indicated, less by a factor of 20 than the current OSHA guidelines of 10  $\text{mW}/\text{cm}^2$  for working areas. With an additional safety factor of 10 for a public environmental standard, an exposure level of 50  $\mu\text{W}/\text{cm}^2$  is recommended. These proposed regulations apply to MW and RF stationary transmitters. However, similar biologic considerations apply to MW and RF radiation from mobile units (e.g., citizen band radios); hazards associated with these types of units are incompletely evaluated and merit careful public health surveillance.

- 6398 CAN HIGH VOLTAGE CAUSE ENVIRONMENTAL HAZARDS? (Nor.) Anonymous. (No affiliation given). *Teknisk Ukeblad Teknisk* 126(35): 16; 1979. (3 refs)

The environmental hazards of high-voltage power transmission lines are discussed. The electric field intensity can reach up to 100 V/cm directly under a 765,000 V-line, to about 50 V/cm at a 30-m distance, and to 5 V/cm at a 60-m distance. Some of the most sensitive pacemakers can be affected by the electric field around high-voltage power lines. A study conducted among 250 workers of 500- and 750-kV transformer stations in the USSR demonstrated such common symptoms as headache, weakness, and malaise. Reduced growth of rats and mice; stress and increased pulse rate and blood pressure in dogs; and behavior and physiologic changes in fish, birds, rabbits, monkeys, and bees were seen after exposure to electric field intensities that occur in the vicinity of high-voltage power transmission lines.

- 6399 BIOLOGIC EFFECTS OF MAGNETIC FIELDS. (Cze.) Jerabek, J. (Centrum hygieny prace a nemoci z povolani, Institut hygieny a epidemiologie, Srobarova 48, 100 42 Prague 10, Czechoslovakia). *Prac Lek* 31(3): 98-106; 1979. (68 refs)

Studies on the biologic effects of magnetic fields are reviewed. Colonies of *Micrococcus prodigiosus* demonstrated morphologic changes in a magnetic field. Progressive atrophy was seen in *Coxphyllum maris*, *Colpidium*, *Stylonichia*, *Oxytricha*, and *Vorticella* in a magnetic field (5-8 kOe). Exposure to a 7.3-kOe magnetic field reduced the oxygen consumption by mouse embryos. Exposure to 100 Oe (50 Hz for 6.5 hr) caused a highly significant susceptibility of rats to *Listeria* infection by impairing the immune defense. Magnetic fields can also cause functional disorders in the nervous system. Occupations linked with exposure to magnetic fields are listed along with the principal physical parameters of exposure.

- 6400 BIOLOGIC EFFECTS OF ELECTROMAGNETIC FIELDS. (Ger.) Bernhardt, J. (Institut fur Radiologie, Krankenhausstr. 12, D-8520 Erlangen, W. Germany). *Z Naturforsch [C]* 34(7): 616-627; 1979. (89 refs)

The biologic effects of electromagnetic fields on humans are reviewed with special emphasis on the thermal effects. The maximum permissible energy density for long-term exposure is set at 10  $\text{mW}/\text{cm}^2$  in western countries, which corresponds to a heat production of about 1  $\text{mW}/\text{cm}^3$  of tissue. Microwave radiation energies of 100-1,000  $\text{mW}/\text{cm}^2$  are used therapeutically. The formation of cataracts have been observed at energy densities exceeding 100  $\text{mW}/\text{cm}^2$ . For frequencies below about 30 kHz, excitation processes cannot be excluded in exceptional cases. Between 30 and 100 kHz, thermal effects are predominant before excitation can appear. Artificially generated currents with frequencies and intensities of the same orders of magnitude of those of the electroencephalogram currents may affect the central nervous system, but they are not hazardous. At frequencies around 10 kHz and a current intensity of 10  $\mu\text{A}/\text{cm}^2$ , interactions with physiologic processes taking place on the cell membrane at a time constant of 0.1 msec are possible.

- 6401 LONG-TERM EXPOSURE TO ELECTRIC FIELDS. A CROSS-SECTIONAL EPIDEMIOLOGIC INVESTIGATION OF OCCUPATIONALLY EXPOSED WORKERS IN HIGH-VOLTAGE SUBSTATIONS. (Eng.) Knave, B. (Natl. Board Occupational Safety and Health, S-100 26 Stockholm, Sweden); Gamberale, F.; Bergstrom, S.; Birke, E.; Iregren, A.; Kolmodin-Hedman, B.; Wennberg, A. *Scand J Work Environ Health* 5(2): 115-125; 1979. (34 refs)

Epidemiologic data on 53 substation workers with more than 5 yr of exposure to electric fields of 400 kV were compared with data for a matched reference group of 53 nonexposed workers at the same power stations in Sweden to investigate the possibility of chronic health effects resulting from high-voltage exposure. The investigation included effects on the nervous system, the cardiovascular system, the blood, and fertility. The results showed no significant differences between the exposed and reference groups as a result of long-term electric field exposure. The exposed group did consistently better on psychologic performance tests, but this was attributed to the higher education of the exposed group relative to the reference group. Members of the exposed group also had fewer children, especially boys, than did members of the reference group. However, this difference appeared to be related to factors other than exposure since it existed 10-15 yr prior to employment at the substations. These results offer no evidence for the development of chronic health effects in high-voltage substation workers as a consequence of electric field exposure.

- 6402 REGULATING POSSIBLE HEALTH EFFECTS FROM AC TRANSMISSION LINE ELECTROMAGNETIC FIELDS. (Eng.) Rish, W. R. (Dept. Engineering and Public Policy, Carnegie-Mellon Univ., Pittsburgh, PA 15213); Morgan, M. G. *Proc IEEE* 67(10): 1416-1427; 1979. (47 refs)

Reducing public exposure to alternating current

(AC) transmission line fields is discussed in relation to the uncertainty concerning the possible health effects of such exposure. Available experimental evidence on human health effects due to electromagnetic field exposures from high-voltage transmission lines is limited and inconclusive. The primary basis for public concern is a series of experiments conducted in the Soviet Union that revealed adverse effects such as headaches, sluggishness, fatigue, irritability, poor sleep, and reduced sexual potency in male switchyard workers exposed to electromagnetic fields generated by 400- to 500-kV potentials. Results from a study in Spain appear to support the Soviet findings. However, virtually all research in North America and Western Europe has yielded negative results; to date, slight changes in reaction times and small changes in blood chemistry are the only effects in humans that these investigators have observed. Clinical studies of American linemen and Canadian substation workers as well as a French study of linemen and their families have all failed to uncover any of the effects claimed by the Soviet studies. In the face of this uncertainty concerning possible health effects, it is not possible to perform an analysis that trades an evaluation of known health effects against the costs of controlling exposure to AC transmission lines in a way that will allow for selection of an optimal level of control. A review of various possible control strategies indicates that wider right-of-ways and/or the use of grounded shield wires may warrant serious consideration depending on the specific parameters of the line involved and on subjective opinions about threshold exposure and level of possible undetected per capita health impact.

6403 EFFECTS OF ELECTROMAGNETIC RADIATION ON HUMANS. (Eng.) Lockey, M. W. (No affiliation given). *J Miss State Med Assoc* 20(10): 237; 1979. (0 refs)

A brief editorial on the thermal and nonthermal effects of nonionizing electromagnetic radiation (EMR) is presented. To date, only thermal effects of EMR have been adequately documented. The amount of heat produced in a tissue exposed to EMR is proportional to the level of EMR energy generated by the instrument, time of exposure, and source-to-subject distance. Microwave cataracts are a well documented form of EMR damage in persons working with microwave energy and in persons cooking with faulty microwave ovens. Persons with any metallic implant such as a rod, plate, or other types of medical implants should avoid close exposure to EMR energy sources since the metal heats more rapidly and produces surrounding tissue damage. The effects of EMR on cardiac pacemakers are also well known, and such patients should avoid exposure. Nonthermal effects of EMR that have been reported but not documented include behavioral changes, malaise, restlessness, sterilization, fetal damage, and central nervous system changes. These effects are currently being critically evaluated, especially by the Russian electronic industry. A common non-thermal complaint associated with EMR has been

the occurrence of headaches and mood changes in persons living very close to high-tension power lines that produce EMR.

6404 AIR SAFETY: ROLE OF FAMILY PHYSICIAN. (Eng.) Zaret, M. M. (P.O. Box 388 M, 1230 Post Rd., Scarsdale, NY 10583). *NY State J Med* 79(11): 1694-1698; 1979. (5 refs)

Fifteen cases of acquired capsular cataract in commercial air traffic controllers and airline pilots (ages at onset, 33-55 yr) are reported. In all of these cases, it was confirmed that capsular cataract was acquired following prolonged employment in avionic environments containing spurious nonionizing radiations emitted by radar, radio, navigational devices, cathode ray tubes, video display units, etc. The significance of the capsular type of cataract acquired during adult life in the absence of signs or symptoms of prior intra-ocular inflammatory disease relates to the differential diagnosis. All of the other ordinarily encountered cataracts such as congenital, familial, metabolic, drug, or senile cataracts initially become evident within the lens substance itself instead of at the site of its capsule. All but 1 of the 15 patients with capsular cataract were otherwise healthy. They were required to pass relatively stringent annual Federal Aviation Agency (FAA) physical examinations; each patient had passed until developing the cataracts and therefore failing the visual acuity test. In accordance with the classification of nonionizing radiation cataracts developed in 1973, all of the cases reported here can be identified as "delayed" hertzian radiation cataracts, as differentiated clinically from "acute" or "subacute" types. Delayed hertzian radiation cataracts usually form insidiously over a 5- to 30-yr period. It is during the critical interval, while the cataract is evolving and before significant visual loss has occurred, that it is important to arrive at a correct diagnosis. Not infrequently, during the early months or years, one lens can exhibit opacities while the other lens may still be completely transparent. Regardless of whether the cataracts are bilateral, unilateral, or at markedly different stages in the two eyes, removing the patient from further continuing exposure may result in either a slowing down of the rate of cataractogenesis or a total arrest of the process in a forme fruste stage.

6405 DIFFICULTIES IN THE CERTIFICATION OF MICROWAVE DISEASE. (Pol.) Gluszczyk, M. (Klinika Chorob Zawodowych i Ostrych Zatruc, Instytut Medycyny Pracy, ul. Teresy 8, 90-950 Lodz, Poland). *Med Przemyslowa* 30(2): 147-150; 1979. (4 refs)

The difficulties in the certification of microwave diseases are discussed and three case reports demonstrating this problem are presented. Microwave diseases are difficult to recognize as occupational diseases because the exposure parameters and clinical pictures have not yet been sufficiently identified. A 41-yr-old induction furnace operator (fur-

nance output of 2,000 kHz, 60 kW) developed photo-genic epilepsy, a sensation of warmth in his legs, and other disorders after 17 yr on the job. His condition was recognized as a microwave disease. A second case is that of a 56-yr-old man who worked as a maintenance mechanic at a radio broadcasting station for 8 yr. Sixteen years later, he developed a psycho-organic syndrome; his condition was not recognized on diagnosis as an occupation-related disease. A 37-yr-old ship radio officer developed headache, malaise, and visual and psychic disturbances 8 days after he was accidentally exposed to microwaves while repairing radar equipment. His condition was diagnosed as an occupational disease.

- 6406 CLINICAL ASPECTS OF THE STIMULATION OF BONE HEALING USING ELECTRICAL PHENOMENA. (Eng.) Watson, J. (Electrical Engineering Dept., Univ. Wales, Swansea, Wales, U.K.); Downes, E. M. *Med Biol Eng Comput* 17(2): 161-169; 1979. (32 refs)

Clinical techniques used for electrostimulation of bone healing are described along with some results in patients with nonunions. Stimulation with electric currents may be completely invasive (electrodes are surgically implanted) or semi-invasive (insertion of percutaneous electrodes). The small currents involved allow for the use of light weight power packs so that the patient can be ambulatory. The existence of metallic inclusions (screws, plates, etc.) does not preclude the use of this method. Electrostatic stimulation using electret films has been used in only a small number of patients; thus, a proper evaluation of the technique is difficult. This method requires no power supply, but it is doubly invasive. Magnetic field stimulation with air-cored coils is a completely noninvasive system and is potentially fully portable with the use of rechargeable nickel-cadmium batteries. However, it is doubtful that it can be used in the presence of metallic inclusions except in some carefully defined cases. Magnetic field stimulation with iron-cored electromagnets is also completely noninvasive but requires a mains-operated power pack and a magnet heavy enough to preclude ambulation. However, the field is closely defined so that the technique may be used where metallic inclusions are sufficiently remote. There is no evidence illustrating the relative efficacy of the fast rising but brief field pulses of air-cored coils versus the slower rising more protracted fields of iron-core magnets. Results from a long-term clinical trial where patients with various types of acquired nonunion were treated with an orthopedic stimulator electromagnet are reviewed. The stimulator was run continuously for a treatment period of 4-8 wk; total treatment time/day was about 22 hr. An analysis of the first eight patients in this trial revealed that six experienced sound bony union.

- 6407 ELECTRIC STIMULATION OF BONE GROWTH AND REPAIR (ABSTRACT). (Ger.) Burny, F.; Herbst, E.; Hinsekamp, M.; eds. (New York: Spring-

er-Verlag): 93 pp.; 1978. *Zentralbl Chir* 104(7): 477; 1979. (0 refs)

See Current Literature 6362, 6473, and 6474 for description of this article.

- 6408 THE ELECTRICAL STIMULATION OF BONE HEALING. (Eng.) Watson, J. (Electrical Engineering Dept., Univ. Wales, Swansea, Wales, U.K.) *Proc IEEE* 67(9): 1339-1352; 1979. (66 refs)

Studies on electrical stimulation of bone healing are reviewed. In one study using small electrical currents, a multicathode apparatus was used to treat 57 cases of nonunion. The device used a 7.5-V battery along with a field effect transistor (FET) current source to deliver 10  $\mu$ A (or 20  $\mu$ A for large bones) to each of four cathode wires. A stainless steel grid anode was used on the skin surface. Of 57 patients who exhibited nonunion after fracture, 39 (68%) achieved clinical and radiological union after electrical current stimulation. Several of the failures involved mechanical faults such as cathode displacement. Studies of the effects of electric and magnetic fields on bone stimulation are relatively few in comparison to those dealing with electrical currents. However, two animal studies have demonstrated that both static and pulsing electric fields modify bone growth processes. Moreover, one research group has successfully treated at least one patient using an electret method. A crossed pair of electret strips were placed on the periosteum over the fracture line of a patient with a delayed union of the tibia; 15 wk later, x-ray examination revealed callus formation and bone union. The effects of applying pulsed magnetic fields across fibular osteotomies have been investigated in dogs. Pairs of air-cored coils were strapped to each side of the leg so that the axis of their magnetic field crossed the fracture site laterally. When a pulse frequency of 65 pulses/sec and a pulse duration of 0.15 msec were used, subsequent mechanical testing indicated that significant improvement in resistance to bending was present in the stimulated fibulae of 10/13 dogs. Magnetic fields have also been used to treat both acquired and congenital pseudarthroses in humans. Air-cored coils were used for treating patients for whom treatment such as bone grafting had failed. Initially, a single O-shaped coil was used, pulsed at 75 pulses/sec by an electronic module that provided a fast-rising 0.3-msec pulse. Using a search coil (consisting of 50 turns of 30 gauge wire with a 5-mm inside diameter), an induced voltage pulse of about 80 mV was observed at the face of the treatment coil. Progression to union following this treatment was observed in 10/13 patients with acquired pseudarthroses and in 9/11 patients with congenital pseudarthroses. Although electrical stimulation appears to be of value in the treatment of nonunions, the fundamental processes occurring as a result of stimulation are not understood fully.

- 6409 ELECTROMAGNETIC FIELDS AND ALTERNATING CURRENT. DO THEY ACCELERATE BONE HEALING?

(Ger.) Sturmer, K. M. (Abteilung für Unfallchirurgie, Gesamthochschule Essen, Hufelandstr. 55, D-4300 Essen, W. Germany); Kehr, H.; Schmit-Neuburg, K. P. *Zentralbl Chir* 104(12): 777-790; 1979. (15 refs)

The effect of magnetic field on the healing of bone nonunions was studied in twenty-one 4-yr-old female beagles with 4-mo-old identical atrophic nonunions of both ulnae. The nonunions were stabilized with plates and treated electrically for 4 wk, with the nonirradiated ulna serving as a control. Ten of the 21 animals were exposed to a magnetic field with 50 G, 22 Hz for 10 hr/day, while another group of 10 dogs, in which cancellous bone graft was inserted, was exposed to 50 G, 38 Hz for 14 hr/day. The qualitative and quantitative evaluation of the x-rays of nondecalcified bone showed better bone healing in the group with cancellous bone graft on the treated side compared with the nonirradiated side, but there was no significant difference between the two sides in the first group. The better results in the second group may be due either to the cancellous bone graft or to the more intense irradiation.

6410 MICROWAVE THERMOGRAPHY: PRINCIPLES, METHODS AND CLINICAL APPLICATIONS. (Eng.) Myers, P. C. (Dept. Physics and Res. Lab. Electronics, Massachusetts Inst. Technology, Cambridge, MA 02139); Sadowsky, N. L.; Barrett, A. H. *J Microwave Power* 14(2): 105-115; 1979. (21 refs)

Medical applications of microwave thermography (MT) are discussed, with particular reference to a study of breast cancer detection at microwave frequencies of 1.3 and 3.3 GHz. True positive (TP) and true negative (TN) rates for about 1,000 normal patients and 29 breast cancer patients were analyzed for detection by MT, infrared thermography (IRT), xeromammography (X), and several combinations as the corresponding detection thresholds were varied. With regard to the frequency of MT, the TP rate at each value of TN for 1.3-GHz MT exceeded the TP rate for 3.3-GHz MT by about 10%; i.e., MT at 1.3 GHz detects more cancers than at 3.3 GHz. A comparison of 1.3-GHz MT results with IRT results shows that at a TN of 0.65, both methods have a TP of 0.75; thus their statistical performance is extremely similar. However, among the 29 cancer cases examined, the MT and IRT methods disagreed in their diagnoses in 12 cases (41%). This is a higher rate of disagreement than that of the MT and X methods (24%) or of the IRT and X methods (28%). This lack of correlation is evident when the MT and IRT criteria are combined; the TP rate is thereby increased by about 10% over that of either method alone. The combination of MT and IRT in breast cancer detection offers a potential alternative to x-ray examination, as it can detect as many cancers as the latter with about the same TN rate but without the hazards of x-ray exposure.

6411 THERAPEUTIC POTENTIAL OF CONFORMAL APPLICATORS FOR INDUCTION OF HYPERTHERMIA. (Eng.) Mendecki, J. (Dept. Radiotherapy, Monte-

flore Hosp. and Medical Center, Bronx, NY 10467); Friedenthal, E.; Botstein, C.; Sterzer, F.; Paglione, R. *J Microwave Power* 14(2): 139-144; 1979. (8 refs)

Preliminary measurements of heat distribution in volumes of tissues placed between two conformal applicators energized at 2.45 GHz are presented. The conformal applicators consist of a printed-circuit antenna array comprising a multiplicity of dipoles, typically a 4 x 4 dipole array. The antenna board with its printed array of dipoles and its backing metal cavity, designed for operation at about 10 GHz, is filled with a powder of high relative dielectric constant so that its actual operating frequency is reduced to the treatment frequency of 2.45 GHz. In addition, a flexible plastic bag filled with the same powder is attached to the rim of the metal box in front of the printed antenna board to form a bean-bag type of applicator that conforms closely to the contours of the treated area. A metallic shield confines the microwave energy to the immediate vicinity of the bag. In order to achieve maximum absorption of the microwaves emitted from the applicator into the irradiated volume, a commercial double-slug tuner serves to match the system and minimize reflected power. Uniform temperature distribution was obtained with this system in a 5-cm thick piece of meat, while a distinct temperature peak appeared at the center of a 3-cm piece and a concave heat distribution pattern was obtained when a 7-cm thick slab of meat was used. In vivo experiments were performed in which the two applicators were positioned on two sides of the left gluteus major of an anesthetized 80-pound dog. The distance between the two applicators was approximately 5 cm. An approximately uniform temperature of 42.5 C was obtained across the thickness of the muscle mass. The conformal microwave applicators are eventually intended for use in the hyperthermic treatment of breast tumors.

6412 FEASIBILITY OF FOCUSED MICROWAVE ARRAY SYSTEM FOR TUMOUR IRRADIATION. (Eng.) Anderson, A. P. (Dept. Electronic and Electrical Engineering, Univ. Sheffield, Mappin St., Sheffield S1 3JD, England); Melek, M.; Brown, B. H. *Electron Lett* 15(18): 564-565; 1979. (6 refs)

A focused microwave array system for producing localized tumor hyperthermia is theoretically proposed. The microwave applicator operates at a frequency of 2.45 GHz, at which the wavelength in body tissue is typically 20 mm. The focused array antenna configuration would produce a hot spot within the body corresponding to the tumor volume to be heated while an acceptable temperature on the skin and in the surrounding healthy tissue would be maintained. The principle of the array system is illustrated by a two-dimensional simulation. Two orthogonal linear arrays consisting of discrete numbers of radiating elements are required to produce a focal spot at the tumor site within one quadrant of a body section delineated by an ellipse. The arrays are screened by ideal reflectors that produce two image arrays. For the purpose of simulation, ideal microwave-absorbing ma-

CURRENT LITERATURE

terial is placed opposite the two image arrays. The amplitude and phase of excitation of each radiator are adjusted to produce a suitable focal spot region within the body to be heated, which is assumed to be a homogeneous attenuating region immersed in a matching lossless dielectric medium. Although the focal region of a focused linear array has a depth several times greater than its width, superposition of two orthogonal focal regions can produce a region with a depth/width ratio equal to unity if required. Thus, the required shape of the focal region can be synthesized by controlling the array-illumination function. An example of the microwave-intensity distribution attainable with realistic system parameters indicates that the focused microwave array system should be able to sustain a raised temperature in the focal region of several degrees above that of the surrounding attenuating tissue. This approach offers flexibility in choice of position, shape, and temperature gradient in the tumor for given temperature limits elsewhere. The heating system is adaptable to microcomputer control with television display. Tumor distribution could be determined from x-ray computerized tomography scanner images, and microwave acquisition could be furthered by locking onto a small implanted scatterer.

- 6413 MICROWAVE RADIOMETRY: ITS POSSIBLE BIOMEDICAL APPLICATIONS. (Fre.) Mamouni, A. (Centre Hyperfréquences et Semi-conducteurs, E.R.A. au C.N.R.S., no. 454, Université des Sciences et Techniques de Lille, B.P. no. 36, 59650 Villeneuve d'Ascq, France); Bliot, F.; Leroy, Y.; Moschetto, Y. *J Fr Biophys Med Nucl* 2(5): 221-224; 1978. (14 refs)

The physical principles of microwave radiometric measurement of temperature and the biomedical applications of this method are described. Microwave radiometers operating in the GHz range are able to sense minute temperature differences, e.g., 0.1 C. Thus, microwave radiometers are of great value potentially in diagnostics, e.g., in the diagnosis of cancer of the lungs and breast, due to their ability to detect minor temperature differences between normal and malignant tissues. Compared with infrared temperature measurement, the microwave radiometers are better suited for the determination of subcutaneous temperatures.

- 6414 NUMERICAL CALCULATION OF ELECTROMAGNETIC ENERGY AND TEMPERATURE DISTRIBUTION IN A MICROWAVE IRRADIATED BREAST CARCINOMA: PRELIMINARY RESULTS. (Eng.) Zimmer, R. (Laboratoire d'Electroradiologie, Faculté de Médecine, 11, rue Humann, 67085 Strasbourg, Cedex, France); Gros, C. M. *J Microwave Power* 14(2): 155-158; 1979. (4 refs)

A numerical calculation of the temperature distribution in a breast tumor model irradiated by microwaves is presented. The model is considered in two parts: an electromagnetic (EM) part used to calculate the energy distribution resulting from microwave irradiation and a thermal part showing the

temperature pattern resulting from the calculated energy distribution. In the EM part, an ellipsoidal model is used to approximate the breast tumor irradiated by a plane wave. The inside and outside fields are calculated by a computer and are depicted in three-dimensional and densitographic formats. The computations, done by an analytical method, are performed for different frequencies, conductivities, and tumor shapes. It is assumed that the conductivity of the outside media is equal to zero, but the relative permittivities of both outside and inside media are different from that of the free space. For the thermal part, the model consists of an ellipsoidal tumor surrounded by an ellipsoidal capillary system. The boundary of the model (i.e., skin of the breast) is also ellipsoidal. Certain assumptions are made regarding heat transfer, thermal conductivity variations, and heat source distribution as calculated from the EM model. The calculations are done in 400 points by a method derived from the Crank-Nicholson method with a time increment of 30 sec. Combining the two models, thermal patterns versus time are calculated after 10 min of heating and at 5 and 10 min following the heating period. These preliminary results show that it is not easy to obtain a uniform thermal distribution due to very low values of thermal conductivity and nonuniform microwave energy distribution. The computation provides evidence of a strong interdependence between frequency, conductivity, shape, and EM energy distribution (i.e., thermal source distribution).

- 6415 CENTIMETER- AND MILLIMETER-WAVE THERMOGRAPHY--A SURVEY ON TUMOR DETECTION. (Eng.) Edrich, J. (Univ. Denver, Denver, CO 80208). *J Microwave Power* 14(2): 95-104; 1979. (33 refs)

Clinical applications of centimeter-wave and millimeter-wave (MMW) thermography are reviewed. Contacting thermography at long centimeter wavelengths has been used to examine confirmed breast cancer cases. When 70 women were examined with 3.3-GHz thermography and 25 with 1.3-GHz thermography, a cancer detection rate of about 70% and a false alarm rate of about 30% were found. These values are similar to the corresponding rates for infrared (IR) thermography. Remote sensing thermography using focused apertures has been studied for imaging purposes at short centimeter and long millimeter wavelengths. Limited clinical trials have been performed for over 1 yr and are now being expanded to clinical screening of large populations of women with suspected breast pathology. A comparison of 68-GHz MMW thermography with IR thermography in a patient with a cancerous lesion of the right breast (confirmed by xeromammogram) revealed several differences. The MMW thermograms were smoother and less spotty than the IR. Temperature variations in the diseased breast were larger for MMW ( $\pm 4$  C) than for IR ( $\pm 2$  C). The average temperature of the entire right diseased breast was about equal to the temperature of the entire left normal breast at MMW; however, averaging only over the hottest area of the left and right side showed that the right side was hotter by about 2 C according to MMW. At IR wavelengths,



both averages yielded a lower temperature on the left side. Finally, the cancer lesion, as located by mammography, was characterized by an extended hot spot with MMW thermography, whereas the IR picture exhibited a generally cool area. Other abnormalities that have been localized by MMW thermography include arthritic joints, abnormalities in the spine, and tumors of the thyroid gland and brain. The use of multifrequency scanners (9, 30, and 68 GHz) for three-dimensional probing of subcutaneous hot spots is currently being studied.

- 6416 MILLIMETER-WAVE THERMOGRAPHY--APPLICATION TO BREAST CANCER. (Eng.) Gautherie, M. (French Natl. Inst. for Health and Medical Res. Lab. Biomedical Thermology, Faculty Medicine, 67085 Strasbourg, France); Edrich, J.; Zimmer, R.; Guerguin-Kern, J. L.; Robert, J. *J Microwave Power* 14(2): 123-129; 1979. (20 refs)

Millimeter-wave (MMW) thermographic studies of 14 breast cancer patients were performed at frequencies of either 30 GHz (6 patients) or 68 GHz (8 patients), and the results were compared with those from infrared (IR) thermograms. Both IR and MMW thermographic examinations were performed under thermally controlled conditions in a room with adequate electromagnetic shielding and thermal uniformity. Significant discrepancies were observed between IR and MMW thermography. In three cases, two of which corresponded to nonpalpable carcinomas in situ, IR thermography was negative while MMW thermography clearly showed hyperthermia. In three patients with 2T1 and 1T2 carcinomas (I.U.S.C. nomenclature) with superficial tumor depths of less than 2.5 cm, local hyperthermia corresponding to the tumor was observed with MMW thermography while intense vascular hyperthermia with anarchic patterns over wide regions was observed on IR thermograms. In five patients with relatively deep (3-5.5 cm) tumors corresponding to 1T1, 3T2, and 1T3 carcinomas of the scirrhous type, no anomaly appeared on the MMW thermogram, whereas IR thermography was positive with intense vascular hyperthermia up to 4 C in two cases. In three patients who had received radiotherapy (RT) for 1T3 and 1T4 tumors, both techniques were positive; however, the hyperthermia characteristics were local or diffuse on the MMW thermogram and of the vascular type on the IR thermogram. In two patients where skin reactions induced by RT were clinically noticeable, diffuse hyperthermia of the whole treated breast was seen on the IR thermogram, whereas no relevant anomaly was seen on the MMW thermogram. In general, it seems that MMW thermography, especially at 30 GHz, is able to provide information on subcutaneous thermal conditions and can be positive in cases of carcinoma in situ that generally are false negatives on IR thermograms. Also, MMW thermograms do not exhibit curvilinear hyperthermia similar to that often observed on IR thermograms as a result of very superficial veins.

- 6417 PROSPECTS OF USING LOCAL UHF HYPERTHERMIA COMBINED WITH RADIATION THERAPY OF MALIGNANT

TUMORS. (Rus.) Lopatin, V. F. (Res. Inst. Medical Radiology, USSR Acad. Medical Sciences, Obninsk, USSR); Dedenkov, A. N. *Med Radiol (Mosk)* 24(9): 9-13; 1979. (13 refs)

The effects of ultra-high frequency (UHF) hyperthermia (41-42.5 C, 40-60 min) combined with gamma radiation (900-2,200 rads) on the growth of sarcoma 180 in 98 outbred mice and on the growth of the R-1 tumor in 56 Wag rats were studied. UHF hyperthermia alone caused only an insignificant and temporary tumor-inhibiting effect, but it significantly enhanced the tumor inhibiting effect of gamma radiation, especially when given immediately before irradiation; 100% tumor inhibition was observed after irradiation with 2,200 rads and UHF hyperthermia 20 days after treatment. UHF fields causing only moderate hyperthermia (41-41.5 C) prevented the radiation injury of the tissues.

- 6418 UHF RADIATION EFFECT ON SARCOMA 180 GROWTH. (Rus.) Lopatin, V. F. (Res. Inst. Medical Radiology, USSR Acad. Medical Sciences, Obninsk, USSR); Dedenkov, A. N. *Vopr Onkol* 25(8): 75-77; 1979. (8 refs)

The tumor growth-inhibiting effect of low-intensity ultra-high frequency (UHF) irradiation (15 W) was studied in mice with subcutaneously transplanted sarcoma 180. The rectal temperature of the animals was maintained at 36-37 C during the irradiation. In one series, the animals were irradiated for 0.15-2 hr/day for 10 consecutive days, beginning on day 7 after tumor transplantation. The animals were sacrificed on day 20. The tumor growth inhibition was 31% for 0.15 hr/day, 62% for 0.5 hr/day, 47% for 1 hr/day, and 56% for 2 hr/day, averaging 49% for the entire series (i.e., the average tumor weight was 49% lower than in the nonirradiated controls;  $p < 0.05$ ). The tumor growth inhibition was 60% in another series in which the animals were irradiated for 0.5 hr/day for 10 consecutive days, beginning on day 10; there was a 56% inhibition after irradiation at 0.5 hr/day for 5 consecutive days. A single 0.5-hr irradiation had no effect on the tumor growth. The average survival time of the tumor-bearing animals increased by a factor of 1.5 as a result of the irradiation.

- 6419 COMBINED TREATMENT OF RADIORESISTANT MALIGNANT TUMORS WITH HIGH FREQUENCY HYPERTHERMIA AND  $\gamma$ -RAYS THERAPY--RECENT RESULTS. (Eng.) Hymmen, U. (Klinikum der Universität Heidelberg, Zentrum Radiologie, Abt. Allgemeine Radiologie und Poliklinik, Strahlenklinik, Vossstr. 3, 69 Heidelberg, W. Germany); Wieland, C. *J Microwave Power* 14(2): 173-180; 1979. (12 refs)

Radio frequency hyperthermia (433.92 MHz) and  $\gamma$ -ray radiotherapy were used to treat 52 patients with relatively radioresistant tumors. Most of the tumors were either squamous cell carcinomas (21 patients) or soft tissue sarcomas (10 patients). Tumors were preheated with 433.92-MHz hyperthermia for 5-7 min, with the tumor temperature after 5 min

## CURRENT LITERATURE

Biological Effects of Nonionizing Electromagnetic Radiation IV(3), March 1980

being 40-42 C. After hyperthermia, γ-ray therapy was delivered at a daily dose of 170-200 rads, 5 times/wk to a maximum total tumor dose of 6,000-6,500 rads in most cases. Among 42 patients evaluated for response, 29 achieved a 100% tumor response; 9, a 75% response; and 2, a 50% response. There were only two local recurrences, and distant metastases were seen in only four patients. Normal tissue exhibited excellent tolerance to this therapy. It is concluded that this combined treatment is superior to megavoltage radiotherapy alone in radioresistant tumors.

- 6420 CANCER THERAPY WITH LOCALIZED HYPERTHERMIA USING AN INVASIVE MICROWAVE SYSTEM. (Eng.) Douple, E. B. (Dartmouth Hitchcock Medical Center, Hanover, NH 03755); Strohbehn, J. W.; Bowers, E. D.; Walsh, J. E. *J Microwave Power* 14(2): 181-186; 1979. (10 refs)

An invasive needle microwave antenna for producing local hyperthermia in small animal tumors was used to treat mammary adenocarcinomas (MTG-B) implanted in the thighs of C3H mice. A sweep oscillator, crystal detector, oscilloscope, and double-stub tuner matching network were used to maximize radiated power to a 50-ohm load for antennas inserted into tumors. For tumor heating the sweep oscillator was replaced by a 3-W, 1-GHz oscillator and a power supply. The antenna was inserted until approximately 1-2 mm of the outer conductor was inside the tumor, a condition that was important for achieving an electrical match in the tissue. The temperature at the antenna was maintained at 46 C by manually regulating the voltage supply to the oscillator. The thermal distributions produced were characterized in MTG-B tumors, and the results suggested that this system is capable of heating a tumor as large as 1 cm in diameter to therapeutic hyperthermia levels of 42-46 C. For therapy trials, 21 mice were divided into three groups of 7 animals each. Mice in the treatment group were placed in the system with an antenna inserted approximately in the center of the tumor and were treated for 50 min with the temperature at the antenna being 46 C. Animals in a sham-treatment group were subjected to the identical regimen but without power supplied to the antenna. Control animals were given anesthesia only. On the 3rd day after treatment a trend was established, with the heat-treated tumor sizes being significantly smaller at the 95% probability level than those of either control or sham-treated tumors. Tumor growth was inhibited for only a short time following treatment (not specified); after the initial post-treatment period, the growth rate of heat-treated tumors was the same as that for both sham-treated and control tumors. The mean survival time of microwave-treated mice was 14.3 days after treatment compared with 11.7 days for sham-treated mice and 11.3 days for controls. These differences were not statistically significant at the 0.05 confidence level. The development of the antenna for incorporation into a percutaneous probe or a catheter could render this system a useful tool for clinical applications

such as the heating of deep-seated, well-defined tumor volumes.

- 6421 HUMAN HYPERTHERMIC THERAPY: RELATION BETWEEN TUMOR TYPE AND CAPACITY TO INDUCE HYPERTHERMIA BY RADIOFREQUENCY. (Eng.) Storm, F. K. (54-140 Center for the Health Sciences, Univ. California, Los Angeles, CA 90024); Harrison, W. H.; Elliott, R. S.; Hatzitheofilou, C.; Morton, D. L. *Am J Surg* 138(1): 170-174; 1979. (18 refs)

The possible relationship between tumor type and ability to induce localized radio frequency hyperthermia was investigated in 46 patients with histologically proved cancer that continued to progress despite standard therapy. A total of 52 solid tumors (18 melanomas, 13 sarcomas, 9 adenocarcinomas, 3 teratocarcinomas, 2 epidermoid carcinomas, and 7 other less common tumors) were treated with 13.56-MHz radio frequency waves at 50-1,000 W of absorbed power for periods up to 1 hr. Superficial tumors and those with less than 1 cm of overlying normal tissue were treated with experimental surface contact electrodes, with or without surface cooling. Deep subcutaneous and internal tumors were treated by a Magnetron employing circumferential noncontact electrodes to provide uniform deep heat without preferential surface tissue heating. Intratumor temperatures of 42 C or greater in 42 tumors and of 45 C or greater in 23 tumors appeared to be independent of histologic type. In 29/52 tumors, temperatures of 45 C or greater could not be achieved without injury to normal tissues. However, no correlation with tumor type could be established. Hyperthermia was generally well tolerated with virtually no injury to normal tissue in mildly sedated, conscious patients. These findings suggest that potentially tumoricidal hyperthermia may be achieved for treatment of solid human tumors regardless of histologic type.

- 6422 A NEW RADIATION BALANCE MICROWAVE THERMOGRAPH FOR SIMULTANEOUS AND INDEPENDENT TEMPERATURE AND EMISSIVITY MEASUREMENTS. (Eng.) Luedeke, K. M. (Philips GmbH Forschungslaboratorium Hamburg, Vogt-Koelln Strasse 30, 2000 Hamburg 54, W. Germany); Koehler, J.; Kanzenbach, J. *J Microwave Power* 14(2): 117-121; 1979. (1 ref)

A radiation balance microwave thermograph for simultaneous and independent temperature and emissivity measurements is described that overcomes the problem of variable mismatch between the test object and the receiving antenna. Measurement error due to the above problem is eliminated by making the temperature of the receiver equal to that of the object. This effect is accomplished by employing the receiver to measure the difference between the incoming and outgoing radiation flux, which equals the production of emissivity and the temperature difference between the receiver and the test object. An integrating servo amplifier controls a variable noise source that adds excess thermal radiation to the receiver's outgoing radiation flux such that the receiver temperature and the

test object's temperature are in balance. The system works as long as the emissivity is not zero. The front-end components of the radiometer can be regarded as a broadband reflectometer completed to form an emissivity measurement bridge by including the direct signal path to the noise source. This property can be simultaneously exploited by modulation of the noise source and detection of the modulated signal fraction after the first synchronous detector. This self-balancing radiometer permits greater measurement accuracy than that of conventional radiometers in situations where contributions from sources other than the test object can be minimized by direct or at least close application of the antenna. Errors due to undefined source mismatch are eliminated. The automatic error compensation of the radiation balance thermograph was compared with the performance of a conventional radiometer by making a manual scan across the surface of a piece of bacon that consisted of interleaved layers of fat and lean. Prior to the measurement, the meat had been heated homogeneously in a waterbath. While the compensated measurement reveals just a slight decline of the temperature along the scan path, the uncompensated measurement is totally misleading due to variable mismatch. The radiation balance thermograph was also used to measure the emissivity of different regions of the human body relative to several experimental antennas. From this experiment, it was concluded that emissivity values between 70 and 100% are well within the practical range for optimum antennas but may be lower than 50% in cases of improper application. The radiation balance thermograph is insensitive to mismatch and mishandling, whereas any conventional radiometer directly responds with considerable error.

6423 SIMULTANEOUS MICROWAVE LOCAL HEATING AND MICROWAVE THERMOGRAPHY. POSSIBLE CLINICAL APPLICATIONS. (Eng.) N'Guyen, D. D. (Universite des Sciences et Techniques de Lille Centre Hyperfréquences et Semiconducteurs LA au CNRS No. 287 U.E.R. I.E.E.A., Bat P3 BP 36, 59650 Villeneuve D'Ascq, France); Mamouni, A.; Leroy, Y.; Constant, E. *J Microwave Power* 14(2): 135-137; 1979. (3 refs)

A method for combining local microwave heating of subcutaneous living tissue with microwave radiometry in the same system is described that overcomes the problem of intermodulation between the microwave generator circuit and the radiometer circuit. A microwave generator supplies microwave power to the tissue through a probe-applicator (circuit 1) and heats a tissue volume (test volume) that depends on the applicator, the generator frequency, and the dielectric properties of the tissue. The test volume emits thermal radiation that is collected by the applicator. This signal, which is proportional to the temperature in the test volume, can be detected by a radiometer (circuit 2) operating in a bandwidth around a certain frequency. To avoid direct coupling between circuit 1 and circuit 2, these circuits are operated at different frequencies chosen to prevent intermodulation.

In a preliminary experiment where the applicator was a miniature coaxial line dipped in water or in a chunk of beef, the microwave power generator was operated at a frequency of 4.6 GHz, and a filter was used to attenuate harmonics and noise. The radiometer was operated at a frequency of 9.6 GHz with a bandwidth of 60 MHz. Intermodulation between the two circuits was avoided, and fair agreement was found between radiometric and thermocouple temperature measurements. During one experiment, irradiation of a beef sample with 5 W of power resulted in a temperature increase of 8 C in 10 min. The above method has potential application in both the detection and local hyperthermic treatment of diseases like cancer in which the permittivity of the diseased tissue differs from that of the normal tissue.

6424 A MICROWAVE HEATING SYSTEM FOR IMPROVING TEMPERATURE UNIFORMITY IN HEATED TISSUE. (Eng.) Hand, J. W. (MRC Cyclotron Unit, Hammer-smith Hosp., Duane Rd., London W12 0HS, England); Hume, S. P.; Robinson, J. E.; Marigold, J. C.; Field, S. B. *J Microwave Power* 14(2): 145-149; 1979. (6 refs)

A microwave heating system for improving temperature uniformity in heated tissue is described. The system uses parallel-opposed waveguide applicators, operating in the TE<sub>10</sub> mode at 2,450 MHz. The tissue to be heated (exteriorized mouse intestine) is immersed in a liquid bolus (dextran in physiologic salt solution) that is both biologically compatible with and dielectrically similar to the tissue. The liquid bolus improves microwave coupling and avoids shape- and size-dependent absorption characteristics of irregularly shaped tissue. By maintaining the liquid bolus at a temperature close to the target tissue temperature, thermal losses and hence temperature gradients in the tissue are reduced compared with heating in hot liquid alone. This was demonstrated by subjecting a typical transverse section of intestine to microwave heating (30 W) while it was immersed in liquid bolus (43 C) for 30 min. The thermal damage can be contrasted with that which results from immersion in bolus alone. Protection near the mesentery vessels is reduced with the microwave heating system, and the gradients of thermal damage are minimized. This result is confirmed by quantitative results of surviving crypts around the jejunal circumference. The biologically compatible liquid bolus could also be used in direct contact with the skin of patients receiving microwave heating treatments for superficial lesions.

6425 EXPERIMENTAL STUDIES ON THE USE OF MICROWAVES FOR THE LOCALIZED HEAT TREATMENT OF THE PROSTATE. (Eng.) Petrowicz, O. (Inst. Experimental Surgery, Technical Univ., Munich, W. Germany); Heinkelmann, W.; Erhardt, W.; Wriedt-Lubbe, I.; Hepp, W.; Blumel, G. *J Microwave Power* 14(2): 167-171; 1979. (5 refs)

Macroscopic and microscopic changes in the prostate

and surrounding tissues were investigated in 15 sexually mature male mongrel dogs subjected to local microwave hyperthermia (433.9 MHz). The prostate was irradiated for 15-20 min using a rectally insertable applicator consisting of a cylindrical slot antenna with a water-cooled covering. A flexible thermistor probe for temperature measurement was inserted into the prostate via the urethra, and two additional thermistor probes were located surgically on the dorsal and ventral side of the prostate. Four experiments are described in detail because of the variability of experimental parameters. The thermistor probe temperatures ranged from 43.5 to 48 C, and the microwave power used to irradiate the prostate varied from 36 to 90 W during the course of the experiments. In one dog, a slight redness of the rectal mucosa and hyperemia of the rectum near part of the ventral prostate were observed. Histologic examination of the rectum revealed no significant changes. The tissue between the rectum and prostate was gelatinous, and hemorrhage as well as granulocyte infiltration into the capsula and interstitium of the prostate were observed. In another dog, no macroscopic or histologic changes of the prostate were observed. However, the rectum showed hyperemia, hemorrhagia, and coagulations of the mucosal membrane. In a third dog, an edematous swelling of the rectal mucosal membrane was observed, and gelatinous tissue was found between the rectum and prostate. The dorsal part of the prostate was hyperemic and exhibited a reddish-blue coloring. Histologic examination revealed necrosis of the tunica muscularis; necrosis in the parenchyma as well as in the interstitium of the prostate was also seen. In a fourth dog the rectum was edematously thickened, but the prostate was without findings. Histologic changes were similar to those observed in the third dog but were less marked because of the lower treatment temperature in this case (43.5 vs. 44 C). Overall, the results show that local heating of the dog prostate is possible. The undesired hyperthermia of the rectum, as manifested by the above changes, was caused by inadequate contact of the rectum with the cooled antenna covering. The gelatinous tissue between the rectum and prostate may have resulted from hyperthermic edema or surgical manipulation. The pathologic and micromorphologic changes of the prostate were mainly due to hyperthermia. Local hemorrhage in the capsule was partly caused by fixation of the thermistor probes with sutures.

- 6426 MILLIMETER-WAVE THERMOGRAPHY: PRELIMINARY CLINICAL FINDINGS IN HEAD AND NECK DISEASES. (Eng.) Robert, J. (Service de Medecine Nucleaire, Universite de Nancy, 54000, Nancy, France), Edrich, J.; Thouvenot, P.; Gautherie, M.; Escanye, J. M. *J Microwave Power* 14(2): 131-134; 1979. (3 refs)

Three typical cases that illustrate the potential application of millimeter-wave thermography (MWT) in the diagnosis of thyroidal, orbital, and intracranial pathologies are presented. In the first case, the results of cervical anterior scintigraphy

of a patient with hyperthyroidism due to an autonomous nodule in the right thyroid lobe were presented along with the results obtained by infrared (IR) photography and 68-GHz MWT. Despite the coarser resolution of MWT compared with IR, the former appeared to have more structure and better localization capabilities than the latter technique. In another patient with exophthalmos and an overinfected mucocoele of the left frontal sinus, a bone scintigram showed a distinct hyperactivity in the upper part of the orbit. In contrast, an IR thermogram was perfectly normal. However, 68-GHz MWT revealed a supra-orbital hyperthermia on the left side. The third case involved a patient with an extensive vertex osteoma on both sides of the midline that was easily recognizable from the right lateral view of a scintigram. In addition, there was an underlying meningioma that did not cross the medial line, as shown on an anterior brain scintigram. For this case, IR thermography could not be used because of the opacity of hair and bone. However, these tissues are relatively transparent to MWT, and a 30-GHz thermogram of the vertex showed a hot left hemilesion in contrast with the colder right side. It is concluded that the meningioma is responsible for the hyperthermia, while the osteoma probably results in little hyperthermia. Overall, it appears that MWT yields more diagnostic information about subcutaneous and intracranial thermal abnormalities than conventional IR thermography, which is limited to cutaneous temperature measurements.

- 6427 THE MINIMUM INACTIVATED CELL RATIO: A CONCEPT FOR THE ESTIMATION OF BIOLOGICAL EFFECTIVENESS OF HYPERTHERMIC TREATMENT OF TISSUE. (Eng.) Klinger, H. G. (SFB 92 d., Univ. Wurzburg, Pleicherwall 2, D-87, Wurzburg, Germany). *J Microwave Power* 14(2): 151-154; 1979. (4 refs)

The concept of minimum inactivated cell ratio (MIR) is discussed in relation to estimating the biologic effectiveness of hyperthermia in tumor therapy. The MIR, which is important with respect to clinical recurrence of a tumor after hyperthermic treatment, can be calculated by using data from in vitro dose-effect curves in combination with the in vivo temperature field. To illustrate the applicability of the MIR concept, the variation of the MIR with respect to space and heat supply time was calculated for the following model. A spherical region of a tissue with constant temperature diffusivity ( $0.13 \text{ mm}^2/\text{sec}$ ) was heated with a constant power during a heating time "t." The maximum temperature at the center of the heated sphere was limited to 50 C in each case. It was found that for short heating times the temperature field was quite local. However, the minimum biologic effect was insufficient for a hyperthermic treatment. The highest MIR (65%) was found at the center of the sphere, and the main gradient appeared at a distance of 0.6-0.7 cm, where the MIR decreased from 30% to about 5%. For one heating time, the MIR was at a minimum at all radii. Long heating times in the present example (640 sec) yielded a 100% MIR. However, the MIR was still quite high in the

surrounding normal tissue and dropped to 10% only at distances of 1.6 cm.

- 6428 SHORTWAVE AND MICROWAVE DIATHERMY FOR DEEP-TISSUE HEATING. (Eng.) Yang, W. J. (Dept. Mechanical Engineering, Univ. Michigan, Ann Arbor, MI 48109); Wang, J. H. *Med Biol Eng Comput* 17(4): 518-523; 1979. (4 refs)

A theoretical model is developed to simulate the temperature distribution in a three-layer tissue consisting of skin, fat, and muscle heated by short-wave (27.12 MHz) or microwave (915 MHz and 2,456 MHz) radiation. The results under the fixed core temperature condition were in good agreement with *in vivo* data measured at the anterior thigh of human subjects. Shortwave diathermy was superior in producing a broader and more uniform temperature distribution in the musculature, but compared with microwave diathermy, it was a less attractive method of muscle heating, producing a slow rise in the muscular temperature and requiring a higher power density. Microwave diathermy application with a low frequency spectrum produced a temperature distribution with peak values in the musculature near the fat/muscle interface. The temperature profile rose with its peak values shifting toward the fat/muscle interface, and the minimum temperature in the fat layer became more distinct as the frequency and/or power intensity increased. An exposure to high frequency microwave heat at 2,456 MHz produced a temperature distribution with a peak value in the superficial skin tissue, a minimum in the fat layer, and a second peak (lower than the first peak) value in the musculature near the fat/muscle interface. Heating with 915 MHz microwave radiation produced a pronounced temperature rise, with the highest peak being in the musculature. Thus, microwave diathermy at a frequency of 915 MHz is recommended for deep tissue heating.

- 6429 EMPLOYMENT OF MAGNETOTHERAPY IN THE COMPLEX TREATMENT OF PATIENTS WITH ULCERS. (Rus.) Guseva, N. G. (Dept. Physiotherapy, Voroshilovgrad Oblast Clinical Hosp., Voroshilovgrad, USSR); Shelygina, N. M. *Vrach Delo* (7): 5-8; 1979. (7 refs)

The therapeutic effectiveness of magnetotherapy with alternating magnetic fields (20 sessions, 15-20 min/session, intensity 350 or 230 G) was studied in 137 patients with noncomplicated peptic ulcer (92 men and 45 women, aged 17-60 yr). The duration of the disease was 1-5 yr in 78 cases, 5-10 yr in 32, and over 10 yr in 27. Eighty-nine patients received magnetotherapy in addition to the conventional drug treatment; the other 48 patients received drugs only. The radiologic examinations showed the complete disappearance of the ulcer niche in 86/89 irradiated patients and in 38/48 controls. The time necessary for the niche to disappear and for clinical cure was 2-4 days less in the irradiated patients. The pain syndrome was also controlled more rapidly. The gastric motor function improved, and the length of hospitalization

decreased compared with the controls. The magnetotherapy had no adverse side-effects.

- 6430 A PILOT STUDY TO INVESTIGATE SKIN AND TUMOR THERMAL ENHANCEMENT RATIOS OF 41.5-42.0 C HYPERTHERMIA WITH RADIATION. (Eng.) Johnson, R. J. (Dept. Radiation Medicine, Roswell Park Memorial Inst., 666 Elm St., Buffalo, NY 14263); Sandhu, T. S.; Hetzel, F. W.; Song, S. Y.; Bicher, H. I.; Subjeck, J. R.; Kowal, H. S. *Int J Radiat Oncol Biol Phys* 5(7): 947-953; 1979. (16 refs)

Normal tissue and tumor responses resulting from radiotherapy (RT) followed immediately (usually 5 min or less) by 1.5-2.0 hr of 915-MHz microwave-induced hyperthermia (41.5-42.0 C) were measured in 10 patients with multiple metastatic melanoma. The response of normal skin to treatment was measured by evaluating the degree of erythema using a numerical scoring system. Tumor response to treatment was assessed by measuring tumor diameter at follow-up visits. One, three, or four fractions of RT were used with a minimum 72-hr interval between each fraction. The RT dose/fraction was 500, 600, 650, 700, 800, or 900 rads. In some cases, single fractions of 1,000, 1,100, 1,200, or 1,300 rads were used. Two or more control lesions were treated with RT but without heat. Heat was applied using direct skin contact Roswell Park Memorial Institute applicators. Skin cooling was required to obtain equal skin and tumor temperatures. A minimum circular area of 5 cm in diameter was heated to a 41.5 C target temperature. Thermocouple measurements were recorded every 10 min with the power on and 5 sec after the power was turned off for the next 10 sec to allow for the dissipation of any local heating resulting from thermocouple positioning and field interference. Thermometry was performed with a fiber optic probe for surface measurement over the normal skin. In addition, 29-gauge thermocouples were inserted into the tumor center and in its deepest aspect. Thermocouples were inserted at right angles to the electric field of the microwave waveguide excited in the TE<sub>10</sub> mode to minimize local heating effects. Results are presented for patients with at least 1 mo of follow-up. Normal skin reactions to RT and microwave hyperthermia generally ranged from slight to severe erythema. Although good data were difficult to obtain because of frequent short or incomplete follow-ups, some tumors demonstrated 100% regression in response to therapy. The study did demonstrate that superficial tumors up to 4 cm in diameter and 2 cm in depth can be heated with an accuracy of  $\pm 0.5$  C. It was also found that normal skin and subcutaneous tissue can be heated to 41-42 C for periods up to 2 hr after RT without any evidence of thermal damage. It is suggested that skin surface temperature measurements may be underestimated when the thermocouple needle is placed directly on the skin surface, where the tip is exposed to air and the applicator end temperatures may be up to 15 C cooler than the skin surface. A more reliable measurement is made if the thermocouple tip is inserted within the first millimeter of the skin tissue. The thermocouple readings should be checked every 10

min for any electromagnetic artifacts by turning off the microwaves for 10-15 sec.

- 6431 HEART ATTACKS AND GEOMAGNETIC ACTIVITY. (Eng.) Knox, E. G. (Dept. Social Medicine, Univ. Birmingham, Birmingham, England); Armstrong, E.; Lancashire, R.; Wall, M.; Haynes, R. *Nature* 281(5732): 564-565; 1979. (2 refs)

Data on daily admissions for acute myocardial infarction to hospitals in the West Midlands region of the United Kingdom for the years 1969-70 were analyzed for their possible relationship to geomagnetic activity during the same period. The geomagnetic data consisted of the daily sums of the 3-hr Kp-values obtained from catalogues of recordings taken in the U.K. There were 6,298 hospital admissions over a 720-day period, a mean of 8.75/day. The Kp-sums averaged 15.73/day. Analyses were performed with both raw data and logarithmic transformations. Same-day correlation coefficients were calculated between the two values within each of 24 successive 30-day periods. Serial correlations were calculated separately for geomagnetic activity and for heart attack admissions between pairs of readings separated by 1, 2, ..., 31 days. Finally, over the full 720-day period, correlations were calculated between geomagnetic readings on day 0 and hospital admissions on days -15, -14, ..., +14, +15 days. The results were qualitatively similar for the raw and the log-transformed data. Serial correlations of the admission data gave significant values at 7 days ( $r = +0.15$ ), 14 days ( $r = 0.16$ ), and 21 days ( $r = 0.12$ ). A complex day-of-week variation over the full period, mainly characterized by a deficiency of admissions on Sundays, confirmed the validity and demonstrated the origins of this finding. Serial correlations of the geomagnetic data gave significant positive results at 1/2 days ( $r = 0.50$  at 1 day), 16/17/18/19 days (0.17 at 17 days), and 25/26/27/28 days (0.21 at 27 days). The 27-day cycle represents the sun's rotation period. None of the 720-day-period correlations with intervals of -15, ..., 0, ..., +15 days showed significant positive or negative correlations; the greatest absolute value was  $r = +0.06$ . None of the intra-30-day-period same-day correlations between medical and magnetic data gave a significant value, either positive or negative. Despite the fact that the above statistical analysis was sensitive enough to detect serial correlations within each of the individual data sets, it was not possible to confirm Indian observations of a remarkable correlation between daily variations in the geomagnetic field strength and daily admissions to the cardio-thoracic wards of hospitals.

- 6432 NON-INVASIVE TREATMENT OF EXTRACTION WOUNDS IN DOGS BY ELECTROMAGNETIC STIMULATION. (Eng.) van der Kuij, P. (Dept. Prosthetic Dentistry, Sch. Medicine and Dentistry, Free Univ., De Boelelaan 1115, Amsterdam, Netherlands); Vingerling, P. A.; Smitt, P. A.; de Groot, K. *J Bioeng* 2(6): 557-565; 1978. (13 refs)

The effect of a pulsating magnetic field on reducing resorption of the alveolar ridge of 1-yr-old female beagle dogs following extraction of the third and fourth premolars on both sides of the mouth was investigated. One group of six dogs had a bridge containing a magnetic coil that was applied to one side of the mouth and a second bridge without a coil that was applied to the other side of the mouth in the extraction wound area. Another group of four dogs had bridges without magnetic coils. The magnetic coil specifications were as follows: dimensions, 12 by 18 by 3 mm; number of turns, 100; resistance, 3.4 ohms; and self-inductance, 230 microhenry. The signal to drive the coil consisted of a pulsating magnetic field with a frequency of 10 Hz and a pulse length of 2 msec. The magnetic field strength ranged from 6,000 A/m at the middle of the stimulated half of the mandible to only 70 A/m at the middle of the control half of the mandible. A quantitative measurement of the resorption was made with the aid of a reproducible standardized x-ray technique. Resorption of the alveolar ridge following tooth extraction was reduced by 70% for stimulated wounds and by 50% for nonstimulated wounds in dogs receiving the pulsating magnetic field treatment. The reduction in resorption for nonstimulated wounds in stimulated dogs can be explained either by assuming a central mechanism of effect or an effect of the very low field present at the opposite side of the stimulated alveolar ridge.

- 6433 PHYSIOLOGIC EFFECTS OF DEEP HYPOTHERMIA AND MICROWAVE REWARMING: POSSIBLE APPLICATION FOR NEONATAL CARDIAC SURGERY. (Eng.) Westenskow, D. R. (Dept. Anesthesiology, Univ. Utah Coll. Medicine, 50 North Medical Drive, Salt Lake City, UT 84132); Wong, K. C.; Johnson, C. C.; Wilde, C. S. *Anesth Analg (Cleve)* 58(4): 297-301; 1979. (21 refs)

Changes in cardiopulmonary dynamics and whole body oxygen consumption during surface cooling up to 20 C and during microwave rewarming to normothermia were studied in 18 mongrel dogs to investigate the usefulness of microwave rewarming for re-establishing cardiac function and normothermia following deep hypothermia. Following surface cooling to 20 C, a 915-MHz microwave applicator with a maximum of 100 W of power was used to warm the myocardium surface temperature to 40-45 C. A nonmetallic liquid crystal temperature probe was secured to the anterior myocardial surface. As the majority of the heating occurs at this surface, the microwave energy applied was reduced to prevent the temperature from exceeding 45 C. After 2 hr of warming with microwaves, the core temperature reached 33 C. Rewarming was completed with warm water bags. During microwave rewarming, the esophageal temperature rose from 20-32 C linearly with time at a rate of 4.7 C/hr. Whole body oxygen consumption, heart rate, and cardiac output returned to normal at rates equal to the rates at which they decreased during surface cooling. Blood pressure and arterial gases remained adequate. Microwave rewarming thus appears to be useful for

re-establishing cardiac function and normothermia following deep hypothermia.

- 6434 INFLUENCE OF MICROWAVE IRRADIATION ON CULTURED GLIOMA CELLS. I. AN ENZYMATIC AND SCANNING ELECTRON MICROSCOPY STUDY. (Eng.) Zanker, K. S. (Inst. for Experimental Surgery, Technical Univ. Munich, Ismaningerstr. 22, 8000 Munich 80, W. Germany); Jung, R.; Stavrou, D.; Blumel, G. *J Microwave Power* 14(2): 159-162; 1979. (4 refs)

Enzymatic and ultrastructural changes in cultured C<sub>6</sub> glioma cells irradiated with 2.4-GHz microwaves are reported. Cultured cells were irradiated for 10-15 min at temperatures ranging from 48 to 56.3 C. Measurements of plasminogen activator activity after microwave irradiation showed that cells kept at 48 C for 10 min or 49 C for 15 min were relatively unchanged with respect to control cells maintained at 28 C. However, an increase in the temperature and time of irradiation (51.6 C for 13 min or 56.3 C for 15 min) resulted in a dramatic loss of plasminogen activator activity compared with controls. Electron microscopic studies of irradiated cells showed that the surface morphology of C<sub>6</sub> glioma cells remained relatively unchanged up to a cell culture medium temperature of 49 C for 15 min. However, when cells were irradiated such that the cell culture medium temperature rose to 51.6 C for 13 min or 56.3 C for 15 min, the following morphologic changes were observed: holes within the cell membrane, a decrease in microvilli, and destroyed zeiotic blebs. These changes in surface topology are most rationally attributed to alterations of membrane proteins.

- 6435 PERMEABILITY OF THE BLOOD-BRAIN BARRIER TO MANNITOL IN THE RAT FOLLOWING 2,450 MHZ MICROWAVE IRRADIATION. (Eng.) Preston, E. (Div. Biological Sciences, Natl. Res. Council Canada, Ottawa K1A 0R6, Canada); Vavasour, E. J.; Assenheim, H. M. *Brain Res* 174(1): 109-117; 1979. (13 refs)

A radiotracer method was used to determine if 2,450-MHz continuous wave microwave energy increases blood-brain barrier (BBB) permeability in the rat to [<sup>14</sup>C]-labeled mannitol, which is normally excluded from entering the brain. Anesthetized adult rats were irradiated singly for 30 min in the quiet zone of an anechoic chamber at average power densities ranging from 0.1 to 30 mW/cm<sup>2</sup>. Afterwards each rat received an intracarotid bolus injection of [<sup>14</sup>C]-mannitol/[<sup>3</sup>H]-water mixture and was decapitated 15 sec later. Uptake of [<sup>14</sup>C]-mannitol relative to the highly permeable [<sup>3</sup>H]-water was calculated as the brain uptake index (BUI) for four brain regions. Differences between mean BUI values for brain regions removed from microwave-irradiated rats compared to sham-irradiated rats were not significant at the 5% level, and a microwave influence on BBB permeability was not evident. Mean BUI levels for cortex and diencephalon remained close to the 2% level across treatment groups. However, mean BUI values for cerebellum

( $4.24 \pm 0.52$  to  $7.76 \pm 2.06\%$ ) and medulla ( $8.05 \pm 0.97$  to  $16.84 \pm 4.50\%$ ) were much higher than those for diencephalon and cortex, and there was much more variability both within and among treatment groups. The generally higher BUI values in cerebellum and medulla compared with other brain regions were related to the fact that both of these tissues contained more [<sup>14</sup>C]-mannitol and less [<sup>3</sup>H]-water than diencephalon or cortex. Medulla absorbed or retained the least [<sup>3</sup>H]-water of all four tissues, and thus BUI values were highest for this tissue.

- 6436 QUANTITATIVE ANALYSIS OF YEAST CELL IN-ACTIVATION AFTER EXPOSURE TO SHF IRRADIATION. (Rus.) Petin, V. G. (Lab. Biophysics, Res. Inst. Medical Radiology, USSR Acad. Medical Sciences, Obninsk, USSR); Kapul'tsevich, Iu. G. *Tsitologiya* 21(7): 830-835; 1979. (9 refs)

The effect of a super-high frequency (SHF) electromagnetic field (wavelength 12.6 cm, energy density 13, 23, or 35 mW/cm<sup>2</sup>) on the inactivation of diploid, triploid, tetraploid, and hexaploid strains of *Saccharomyces cerevisiae* (strains 211, 300, 301, 400, and 600) was studied, and the results were compared with those obtained by a probability model of the action of electromagnetic irradiation on cells. The model is based on the hypothesis that the probability of successful cell division is determined by the degree of cell damage. The temperature of the cell suspensions was 50-55 C during the irradiation. The effect was assessed 5-7 days after irradiation. The probability of successful division was 0.4 for strain 211, 0.3 for 301, 0.4 for 300 and 600, and 0.5 for 400. At the lowest energy density, the survival rates were 63.2% for strain 301, 43.3% for strain 300, 66.2% for strain 600, and 64.7% for strain 400. At the highest energy density, the survival rates were 12% (strain 301), 9.5% (300), 0.5% (600), and 1.0% (400). The percent of cells that died without division after the irradiation was (at the lowest energy density) 17% for strain 311, 66% for strain 300, 39% for strain 600, and 25% for strain 400. The results showed good agreement with the values calculated from the model.

- 6437 PRELIMINARY STUDY OF THE CUMULATIVE EFFECT OF MICROWAVE RADIATION (2,450 MHZ) ON THE IMMUNE RESPONSE OF THE MOUSE. (Fre.) Robert, D. (Division de Microbiologie, CRSSA, 108 boulevard Pinel, 69272 Lyon Cedex 1, France); Deschaux, P.; Pellissier, J. P.; Santini, R.; Fontanges, R. *C R Soc Biol (Paris)* 172(6): 1148-1154; 1978. (10 refs)

The effect of microwave irradiation (2,450 MHz, 10 mW/cm<sup>2</sup>, 1-4 hr/day on 4 consecutive days) on the immune response of 2-mo-old Swiss mice was studied using the Plaque-Forming Cell test (antibody production to sheep red blood cells) and by determining the 20-day survival rate following vaccination with ribosome and membrane fractions of *Klebsiella pneumoniae*. Highly significant stimulation of antibody production was seen in animals irradiated for

## CURRENT LITERATURE

Biological Effects of Nonionizing Electromagnetic Radiation IV(3), March 1980

4 hr/day on 4 consecutive days. Irradiation for 1-3 hr/day on 4 consecutive days had no protective effect against challenge, and there was no significant difference in the survival rate compared with nonirradiated controls. However, a statistically significant increase in the survival rate was seen in animals irradiated for 4 hr/day for 4 days.

6438 FURTHER PROGRESS WITH ONCOLYSIS DUE TO LOCAL HIGH FREQUENCY HYPERTHERMIA, LOCAL X-IRRADIATION AND APATHOGENIC CLOSTRIDIA. (Eng.) Gericke, D. (Hoechst Ag, 6230 Frankfurt/Main 80, W. Germany); Dietzel, F.; Ruster, I. *J Microwave Power* 14(2): 163-166, 1979. (11 refs)

The oncolytic effect of local x-irradiation, local high-frequency hyperthermia (HFH), and treatment with apathogenic *Clostridia* is reported. Fifty NMRI mice received a subcutaneous transplant in the neck of a Harding-Passey melanoma. When the tumor diameter reached at least 8 mm, the mice received x-irradiation (2,000 rads), followed immediately by 461-MHz HFH (40-41 C for 3 min), and followed 12 hr later by an injection into the tail vein of  $10^8$  spores of *Clostridium oncolyticum* s. *butyricum*. After one cycle of this treatment, only 10% of the mice were free of tumor relapse; however, this percent rose to more than 30% after two cycles of treatment and to more than 60% after six treatment cycles. Oncolysis occurred after each repeated spore application, and treatment was well tolerated.

6439 EFFECT OF CONTROLLED ELECTROMAGNETIC RADIATION ON THE GROWTH OF CELLS IN TISSUE CULTURE. (Eng.) Peters, W. J. (Suite 1-120, Univ. Wing, Toronto General Hosp., 101 College St., Toronto, Ontario M5G 1L7, Canada); Jackson, R. W.; Iwano, K. *J Surg Res* 27(1): 8-13; 1979. (24 refs)

Various mammalian and bacterial cell lines were exposed for 1 min or multiples of 1 min to microwave (MW) radiation at a wavelength of 12 cm, a frequency of 2.45 GHz, and a current of 120 mA under strictly controlled temperature conditions to assess the effect of this exposure on their growth in tissue culture. When L-929 cells were exposed to five 1-min doses of MW energy, subsequent growth was significantly decreased. The maximum temperature reached during irradiation was 34-35 C. When these cells were alternately cooled in an ice bath (0 C) and placed in a water bath (34-35 C) for five 1-min exposures, their subsequent growth was not affected. The sensitivity of suspension cultures of asynchronous L60T cells to MW radiation was similar to that of L-929 cells, and alternate cooling and heating again had no effect on their growth. In experiments where L60T cells were synchronized and subsequently exposed to five 1-min doses of MW energy as the cells progressed through the cell cycle, it was found that cells in the S and G2 phases of the cell cycle were resistant to MW radiation. However, 12% of the cells in the M phase failed to proliferate following MW exposure, and about 45% of those in

the G1 phase failed to form colonies after MW treatment. The susceptibility of L60T cells during the G1 phase suggested that if an asynchronous population were treated at four successive 4-hr intervals, growth would be inhibited to a greater extent than if the population were treated at four successive 1-hr intervals; this was indeed found to be the case. Preliminary experiments indicated that the growth of VX<sub>2</sub> and RT cells (two cell lines derived from neoplastic tissue) was more sensitive to MW energy than the growth of L cells at comparable energy levels. Intermittent exposure of these cell lines to a water bath (35 C) and an ice bath (0 C) for five 1-min exposure periods had no effect on their subsequent growth. Bacterial cultures of *Staphylococcus aureus*, *Streptococcus pyogenes* and *viridans*, *Bacillus subtilis*, *Escherichia coli*, and *Pseudomonas aeruginosa* were totally resistant to MW irradiation unless the exposure temperature was elevated to destructive levels.

6440 STUDY OF NONIONIZING MICROWAVE RADIATION EFFECTS UPON THE CENTRAL NERVOUS SYSTEM AND BEHAVIOR REACTIONS. (Eng.) Shandala, M. G. (A. N. Marzyev Scientific Res. Inst. Public and Communal Hygiene, Kiev, USSR); Dumanskii, U. D.; Rudnev, M. I.; Ershova, L. K.; Los, I. P. *Environ Health Perspect* 30: 115-121; 1979. (17 refs)

Neurologic, behavioral, and immunologic reactions of rabbits and rats exposed to far-field irradiation at a frequency of  $2,375 \pm 50$  MHz are reported. In one experiment, 24 rabbits were exposed to continuous wave radiation at power densities of 10, 50, and 500  $\mu\text{W}/\text{cm}^2$  for 7 hr/day over a 3-mo period. Power densities of 10 and 50  $\mu\text{W}/\text{cm}^2$  stimulated brain bioelectric activity, as indicated by an increase in the regularity of the basic theta-rhythm and the degree of similarity of the form of oscillation with a parallel increase in its amplitude in the thalamus and posterior hypothalamus. In the cortex regions, the increase in activity was associated with raised excitability of the brain. A power density of 500  $\mu\text{W}/\text{cm}^2$  suppressed brain bioelectric activity, as evidenced by an increase in slow delta waves of high amplitude that occurred after 2 wk of irradiation in the cortex. A gradual increase in slow high amplitude activity was also seen after 1 mo of irradiation at a power density of 50  $\mu\text{W}/\text{cm}^2$ . In another experiment, rats exposed to 500  $\mu\text{W}/\text{cm}^2$  of radiation for 7 hr/day over a 1-mo period exhibited decreases in work capacity, levels of unconditioned feeding stimulus, investigating activity, and electronic irradiation threshold. This power density also caused a sudden and statistically significant disturbance of the immunologic system; this was manifested by substantial suppression of phagocytic capability of neutrophils and by a reduction of the functional activity of immunocompetent cells responsible for cellular and humoral protection reactions.

6441 ERYTHROCYTE DAMAGE CAUSED BY THE HAEMOTHERM<sup>®</sup> MICROWAVE BLOOD WARNER. (Eng.)



Linko, K. (Dept. Anesthesia, Helsinki Univ. Central Hosp., Haartmanintaku 4, 00290 Helsinki, Finland); Hynynen, K. *Acta Anaesthesiol Scand* 23(4): 320-328; 1979. (15 refs)

Erythrocyte damage to blood units in Fenwal blood bags was examined after water bath warming and after warming by a Haemotherm® microwave blood warmer operating at a frequency of 2,450 MHz. Extracellular hemoglobin and potassium, hematocrit, osmotic fragility, and mean cellular volume were used as indicators of red blood cell damage. Warming in the water bath caused no erythrocyte damage at temperatures of about 46 C. At temperatures above this, progressive hemolysis, swelling, and finally erythrocyte fragmentation were observed. Units of red blood cells in saline warmed to temperatures above 46.3 C with the Haemotherm® showed intense hemolysis and changes in all of the parameters used to assess red blood cell damage; below this temperature no erythrocyte damage occurred. When the amount of blood warmed was less than 300 g or when the hematocrit exceeded 0.70, the blood mixing mechanism became insufficient, leading to local overheating and hemolysis. The mean plasma hemoglobin increase of 10 whole blood units warmed by the Haemotherm® to 36.0-36.8 C was 123 mg/l. The above results indicate that microwaves per se are not harmful to erythrocytes but that penetration of microwaves together with insufficient blood mixing during warming are the critical factors leading to hemolysis.

6442 HOLOGRAPHIC ASSESSMENT OF A HYPOTHESIZED MICROWAVE HEARING MECHANISM. (Eng.) Frey, A. H. (Randomline, Inc., Huntingdon Valley, PA 19006); Coren, E. *Science* 206(4415): 232-234; 1979. (21 refs)

Dynamic time-averaged interferometric holography was used to measure predicted motion in the skull or soft tissue of the heads of rats and guinea pigs exposed to pulsed microwaves to determine if the thermoacoustic expansion-bone conduction hypothesis accounts for sound perception of microwaves in mammals. In one experiment with 10 Sprague-Dawley rats, the microwave energy carrier frequency was 1.275 GHz; the pulse width, 25  $\mu$ sec; the pulse repetition rate, 50 pulses/sec; and the incident peak power, 1,700 mW/cm<sup>2</sup>. In five of the animals, an additional set of holograms was made at 100 pulses/sec as each layer of head tissue was removed, starting with the holograms of the muscle tissue. In a second experiment, 16 adult male guinea pigs were used, half of them being tested at a frequency of 1.1 GHz and the others at 1.2 GHz in a 2 x 2 x 2 factor design. The factors were peak power density at 1,250 and 8,500 mW/cm<sup>2</sup>, pulse width at 10 and 20  $\mu$ sec, and pulse repetition rate at 25 and 50 pulses/sec. A treatment-by-subject design was used in which each animal was its own control. The experiments showed that the predicted motion of head tissue did not occur. Based on this finding and evidence reported elsewhere, it is suggested that the locus of radio frequency hearing is in the

cochlea, where possible thermoacoustic expansion could account for the auditory perception of microwaves.

6443 AN ELECTROMAGNETIC ENERGY COUPLER FOR MEDICAL APPLICATIONS. (Eng.) Iskander, M. F. (Dept. Electrical Engineering, Univ. Utah, Salt Lake City, UT 84112); Durney, C. H. *Proc IEEE* 67(10): 1463-1465; 1979. (12 refs)

An applicator for coupling electromagnetic (EM) energy into a dielectric material such as tissue with minimum leakage radiation is described. The applicator is a printed-circuit 50-ohm surface strip transmission line (coplanar waveguide) that is fed by a small coaxial line and is terminated by a thick-film 50-ohm chip resistor; the ground plane is placed on both sides of the center strip conductor. This geometry allows the spread of EM fields around the transmission line rather than confining them between the conductors. The coupling characteristics of the EM applicator were determined by mapping the fields coupled through a layer of wet sponge, which simulated the tissue, and placing the sponge on top of the applicator. The peak field intensity coupled to the sponge occurred at the contact region with the applicator, and the signal amplitude rapidly decreased as the distance from the contact region increased. The feasibility of using the EM applicator in medical diagnostics was examined by inducing pulmonary edema in the lungs of dogs and using the EM applicator to monitor changes in the microwave (915 MHz)-transmitted signal in vivo. Changes in the phase of the microwave-transmitted signal agreed very well with changes in the pulmonary edema, as indicated by changes in the mean pulmonary arterial pressure. The results obtained from both the phantom and animal experiments illustrate the high coupling efficiency of the applicator with minimum leakage radiation around the body.

6444 MICROWAVE SCATTERING PARAMETER IMAGERY OF AN ISOLATED CANINE KIDNEY. (Eng.) Larsen, L. E. (Dept. Microwave Res., Walter Reed Army Inst. Res., Washington, DC 20012); Jacobi, J. H. *Med Phys* 6(5): 394-403; 1979. (13 refs)

A method for imaging biosystems using microwave radiation is described and illustrated using a phantom brain target and an isolated canine kidney. The images are two-dimensional arrays of microwave transmission coefficients (magnitude and phase of the complex power transmission coefficient  $s_{21}$ ) that depict the relative insertion loss and relative phase shift of a 3.9-GHz signal as it propagates through the specimen. The image is a square array containing a total of 4,096 pixels. At each point in the image, the magnitude and phase of  $s_{21}$  is measured and recorded. The data collection system, consisting of an electromechanical scanner subsystem, a control and recording subsystem, and a microwave stimulus-response measurement subsystem, provides  $s_{21}$  microwave images that can then

## CURRENT LITERATURE

Biological Effects of Nonionizing Electromagnetic Radiation IV(3), March 1980

be related to known organization within the canine kidney. Specifically, the regions thinly populated with glomeruli in the cortex corticis are distinguishable from deeper cortical regions containing large numbers of glomeruli with some suggestion of lobulation. Likewise, the medullary outer zone where the thick loops of Henle are found in greatest proportion is easily distinguished both from deeper cortical layers and the renal pelvis. Thus, regions corresponding to filtration appear to be separable from regions corresponding to osmotic concentration, and these are easily separable from the pelvis. These maps of  $s_{21}$  also allow inferences concerning regions within the kidney that may be especially liable to injury with sufficiently high power microwave fields. To the extent that the interrogation frequency is well removed from the relaxation frequency of water, so that temperature effects on complex permittivity are minimized, the  $s_{21}$  image will represent regions of increased propagation loss (i.e., energy dissipation) for high power fields of the same frequency. It can therefore be inferred that the corticomedullary junction and medullary outer zone are especially liable to microwave injury, and that when sufficient interior fields are induced, the thick regions of the loops of Henle are at special risk. Thus, the hazard can be expected to be expressed as a defect in osmotic concentration rather than, for example, as defects in ultrafiltration.

6445 MICROWAVE INTERFERENCE WITH THE FUNCTION OF AN IMPLANTED CARDIAC PACEMAKER. (Eng.) Neelakantaswamy, P. S. (Sch. Applied Science, Univ. Science Malaysia, Minden, Penang, Malaysia); Ramakrishnan, K. P. *IEEE Trans Electromagn Compat* 21 (3): 274-276; 1979. (8 refs)

A theoretical model is proposed to explain the occurrence of a syncopal episode in a patient with an implanted ventricular sensing cardiac pacemaker who was exposed to 2,450-MHz radiation from a microwave oven. A subsequent clinical study with a similar microwave environment showed a high frequency artifact on recorded electrocardiogram (ECG) tracings, demonstrating effective blocking of the implanted pacing activity. It is theorized that the absorbed microwave energy by the biomedium containing the implanted pacemaker represents a volume of heat source that sets up thermoelastic waves in the biomedium. These acoustic waves induce in the pacemaker circuit noisy microphonic oscillations that correspond to the high frequency artifacts on the ECG tracings. It is suggested that calculation of the amplitude and frequency of the vibration causing the high frequency noise in the pacemaker output would enable the proper design of a pacemaker oscillator circuit with quenched microphonics.

6446 NEGATIVE INFLUENCE OF BIOMAGNETIC EFFECTS ON PUPILS IN LABORATORIES. (Slo.) Tuma, M. (Ustav mechaniky strojov, SAV, Komenskeho 3/35,

C36 01 Martin, Czechoslovakia). *Cesk Hyg* 24(5): 261-264; 1979. (10 refs)

High school and university students are exposed to electromagnetic fields in laboratory practice. The energy can be as high as 1,000-1,000,000 W and the current intensity can reach 1,000 A. The frequency is usually in the range of 10,000 Hz to several GHz. Despite the possible harmful physiologic and mutagenic effects of magnetic fields, no maximum allowable levels have yet been established for students. According to the recommendation of the Stanford Linear Accelerator Center (SLAC), the maximum dose should not exceed 2 Tesla for the arms and legs, and 0.2 Tesla for the whole body.

6447 EFFECT OF SMALL DOSES OF ELECTROMAGNETIC WAVES ON SOME ORGANS AND SYSTEMS OF MAN. (Rus.) Bachurin, V. I. (Dept. Surgery, Zaporozh'e Medical Inst., Zaporozh'e, USSR). *Vrach Delo* (7): 95-97; 1979. (6 refs)

The health status of 100 workers exposed occupationally to electromagnetic fields (20-60  $\mu\text{W}/\text{cm}^2$ , occasionally 100  $\mu\text{W}/\text{cm}^2$ , electric component 20-100 V/m, magnetic component up to 3 A/m) was analyzed as a function of the length of exposure. Ninety workers were less than 45 yr of age. The length of employment involving exposure was 1-5 yr in 42 cases (group 1), 5-9 yr in 24 (group 2), and greater than 10 yr in 34 (group 3). Group 1 workers had practically no complaints, while two workers in group 2 complained about headaches, epicardiac pains, weakness, and somnolence; workers in group 3 also had similar complaints. In group 3, four workers had chronic gastritis and cholecystitis, five had recurrent coryza, four each had angina and radiculitis, and seven had other diseases. Electrocardiogram (ECG) changes (left shift of the axis, sinus tachycardia, disorders in intraventricular conduction, and signs of myocardial hypoxia) were seen in some group 1 workers, usually after 3- to 3.5-yr exposure. The incidence of these ECG changes was higher in groups 2 and 3. Focal opacification of the crystalline lens, arteriosclerosis, and dilation of the veins of the fundus of the eye were found in 3 workers in group 1, in 9 workers in group 2, and in 16 workers in group 3. Vegetative dystonia, asthenoneurotic syndrome, neurovascular dystonia, and neurasthenic syndrome were found in six workers in group 3, and autonomic vascular dystonia was found in two workers in group 2.

6448 ELECTROMAGNETIC INTERFERENCE (EMI) RADIATIVE MEASUREMENTS FOR AUTOMOTIVE APPLICATIONS. (Eng.) Adams, J. W. (Electromagnetic Technology Div., Natl. Engineering Lab., NBS, Boulder, CO 80303); Taggart, H. E.; Kanda, M.; Shafer, J. *NBS Technical Note 1014*, 48 pp.; June, 1979. (5 refs)

Measurements of electric and magnetic field strength levels are reported for the near-field levels in and around full- and compact-sized passenger ve-

hicles and tractor-trailer vehicles. These measurements were made with all common combinations of mobile transmitters and antennas. The radio frequency transmitting sources used the maximum legal output power (110 W) at nominal frequencies of 40, 162, and 416 MHz and nominal 100-W power levels in the high-frequency band (3-30 MHz). Illegal power levels (100 W) of citizens' band transmissions at 27 MHz were used through special authorization by the Interagency Radio Advisory Committee. Fields in and around vehicles with on-board transmitters ranged mostly from 10 to 300 V/m. Field strengths in and around vehicles adjacent to vehicles with transmitters ranged mostly from 5 to 100 V/m. The results of electric field strength measurements in the near-field regions of fixed, high-power transmitters are also reported. These sites included amplitude-modulated (AM), frequency-modulated, and television broadcast stations and high-power military and Federal Aviation Agency fixed transmitters. The electric field strengths in the near-field region of the AM broadcast stations in the frequency range of 550 kHz to 1.6 MHz were much higher than those at other fixed, high-power transmitters, particularly for AM transmitters with 5/8 wavelength towers. Unperturbed fields of over 800 V/m were measured 3 m from the base of a 50-kW, 5/8-wavelength transmitting tower for an AM transmitter operating in the frequency range of 550 kHz to 1.6 MHz. Service vehicles may come within 3 m of a transmitter tower, but at AM frequencies there should be no resonances (since even a tractor-trailer is short compared to wavelengths in the AM frequency range). Based on the measured results, it is concluded that three phenomena are present. (1) Each data curve shows a resonant peak in the 20- to 40-MHz frequency range. Vehicle dimensions (approximately 5 m) are such that a half-wavelength resonance can be expected. There may be other resonances at higher frequencies that were not observed due to the wide frequency separation in the higher test frequencies (above 40 MHz). (2) The field strength levels decrease inversely with the square root of frequency except for the resonant peaks. This follows a skin-effect loss. The metallic vehicle body structure has losses that increase proportionally to the square root of frequency. The more energy that is dissipated in skin-effect losses, the less is available for nondissipative electromagnetic fields. (3) The larger the vehicle, the lower the field strength levels in and around it for equal levels of excitation power. The vehicle is an antenna, but the larger the volume for constant excitation power, the lower the energy density (and hence field strength levels) for this larger volume. All of the measurement results are tabulated in terms of type of vehicle, type of ground surface, frequency, type of field, number of measurements, and five percentile values (100, 95, 90, 75, and 50). Units of measurement for electric fields are V/m, and those for magnetic fields are A/m (far-field V/m equivalent in parenthesis). Although it is recognized that converting A/m to V/m is not valid under near-field conditions, this conversion permits ready comparison of the magnitudes of the magnetic field results with the electric field results on an energy density basis. The magnetic field strength levels were measured with

a magnetic field probe and were not obtained by converting from electric field results. It should be noted that many of the field strength levels measured are much higher than allowed by current American National Standards Institute standards (194 V/m) for personnel exposure. The implications for people who use, manufacture, and regulate these systems could be serious.

6449 ELECTRIC FIELD EFFECT ON THE HELIX-COIL TRANSITION OF POLY(L- $\alpha$ , $\gamma$ -DIAMINOBUTYRIC ACID HYDROCHLORIDE) IN METHANOL/WATER MIXTURES. (Eng.) Fujimori, M. (Dept. Chemistry, Coll. General Education, Univ. Tokyo, Komaba, Meguroku, Tokyo, Japan); Kikuchi, K.; Yoshioka, K.; Kubota, S. *Biopolymers* 18(9): 2005-2013; 1979. (22 refs)

Electric field effects on the helix-coil transition of poly(L- $\alpha$ , $\gamma$ -diaminobutyric acid hydrochloride) in methanol/water mixtures were studied by transient electric birefringence. The electric field was applied to the solution in a Kerr cell in the form of single rectangular pulses. The pulse duration was about 500 usec, and the highest voltage was 7 kV. Anomalous birefringence transients were observed above a certain threshold field strength, and the field strength dependence of the electric birefringence of the solution resembled the behavior of a permanent dipole moment orientation over a limited range of field strengths. The anomalous transients can be interpreted as being due to a conformational change from the charged helix to the charged coil induced by the electric field. A certain fraction of counterions will be bound to the charged helix, but they will be mobile in the axial direction. Application of the electric field displaces such counterions along the helix, giving rise to an induced dipole moment. The helices are then preferentially oriented by the electric field. As the applied field is enhanced, the average degree of orientation becomes larger, causing the component of the field along the helix to increase still more. When the counterions are shifted towards one end of the helix and the increased repulsion between the ionized groups at the other end overcomes the attraction due to the amide hydrogen bonds and other nonbonding interactions, unwinding of the helix will start at that end and propagate along the helix. This process will occur above a critical field on the verge of the transition region. The mechanism involved is analogous to that proposed for field-induced conformation changes in molecules such as deoxyribonucleic acid.

6450 SOME CURRENT RESEARCH TRENDS ON THE BIOLOGIC EFFECTS OF ELECTROMAGNETIC WAVES. (Cze.) Musil, J. (Institut hygieny a epidemiologie, Prague, Czechoslovakia). *Prac Lek* 31(3): 107-108; 1979. (0 refs)

Current research trends on the biologic effects of electromagnetic waves are reviewed in the light of recent conferences and publications on nonionizing radiation. Current research is focused on the action of electromagnetic waves at the cellular,

## CURRENT LITERATURE

Biological Effects of Nonionizing Electromagnetic Radiation IV(3), March 1980

subcellular, and molecular levels; on the effects on the nervous system; on immunologic and hematologic effects; as well as on the possible applications of microwaves for cancer therapy. The ability of microwaves to destroy the blood-brain barrier is also being studied.

- 6451 PERIPHERAL ELECTROSENSE PHYSIOLOGY: A REVIEW OF RECENT FINDINGS. (Eng.) Viancour, T. A. (Dept. Biology, Rice Univ., Houston, TX 77001). *J Physiol (Paris)* 75(4): 321-333; 1979. (44 refs)

Work published since 1974 on the physiology of the peripheral electrosense system of fish is reviewed. The following general topics are covered: species and individual specific stimulus-frequency filtering by tuberous electroreceptors; the role of tuberous electroreceptors in object detection; the sensitivity of ampullary receptors to electric and magnetic fields; and the role of calcium ions in the maintenance of electroreceptor function. Ampullary receptors, which as a class are the most sensitive electroreceptor type, are found in all electric fish and in nonelectric Siluriforms, Chondrosteans, and Elasmobranchs. In Teleosts the threshold for an afferent response is about 1  $\mu\text{V}/\text{cm}$ ; behavioral thresholds are 10-100 times lower. Ampullary receptors are most sensitive to low stimulus frequencies, lower than about 50 Hz and as low as 5 Hz or less. The ongoing activity of the afferent neurons postsynaptic to the ampullary receptor cells is a train of action potential spikes occurring regularly at a rate of 30-80/sec. This afferent activity is modulated by the receptor cells, and the amount of modulation depends on the frequency and intensity of the electric field stimulus. For sinusoidal electric field stimuli, the modulation frequency and the modulation depth is proportional to the stimulus intensity; thus, response frequency is the neural code for stimulus intensity. Concomitant with the ability of electroreceptors to detect electric fields is their ability to detect magnetically induced electric fields. During investigations of the magnetic sensitivity of ampullary electroreceptors in two species of skate (*Trygon pastinaca* and *Raja clavata*), the activity of ampullary afferents was recorded during stimulation with nearly uniform, vertically-oriented magnetic fields. The afferents responded to magnetic fields that were varied at rates of 0.8-20 G/sec but did not respond to static fields. This is consistent with the predicted electric, as opposed to ferromagnetic, detection of magnetic fields. The relationship between the afferent discharge frequency and the rate of change of magnetic induction was approximately linear. Also, the response threshold was proportional to both the length of the ampullary canal and the electric field threshold of the receptor. On the animal's left side, receptors with canals opening rostrally were excited by increasing south (dorso-ventral) directed magnetic fields, while receptors with canals opening caudally were inhibited by these fields. On the animal's right, the rostrally opening receptors were excited by increasing

north directed fields; the caudally opening receptors were inhibited by these fields. Thus an ampullary afferent can be either excited or inhibited depending on the sign of the change in the magnetic field. It has been proposed that the response difference between rostrally and caudally directed receptors is a result of a rostro-caudal induced current loop, with the current flowing from one ampullary group into the other; thus one group is excited while the other is inhibited. The left-right difference may be explained by the induced current patterns that may be a function of the stimulus apparatus. Even without increased sensitivity by central integrative processes, these receptors are sensitive enough to respond when a skate is moving through the earth's magnetic field (0.5 G) at a velocity of 30 cm/sec.

- 6452 EFFECT OF A LOW-INTENSITY ELECTROMAGNETIC FIELD OF ULTRA-HIGH FREQUENCY RANGE ON THE COURSE OF SLOW ALLERGIC REACTIONS. (Rus.) Vinogradov, G. I. (Biologic Hygienic Res. Lab., A. N. Marzeev Kiev Scientific Res. Inst. General and Communal Hygiene, Kiev, USSR); Vinarskaia, E. I. *Vrach Delo* (6): 101-103; 1979. (6 refs)

The effect of an ultra-high frequency electromagnetic field (50  $\mu\text{W}/\text{cm}^2$ , frequency not specified, 7 hr/day for 10-30 consecutive days) on slow delayed contact allergy induced by dinitrochlorobenzene (DNCB) was studied in 78 guinea pigs. DNCB (1% in acetone) was applied topically to the skin for 7 consecutive days; the challenge dose was applied 24 hr after the last treatment. Compared with the nonirradiated animals, the intensity of the dermatitis was significantly reduced in the animals irradiated for 10 days, and even more in those irradiated for 20 or 30 days. The blast transformation of peripheral blood lymphocytes by phytohemagglutinin was also reduced significantly in the irradiated animals (18.6-22.1% versus 31.7-35.4% in the controls). The findings indicate that low-intensity electromagnetic fields of ultra-high frequency induce immune deficiency in thymus-dependent lymphocytes.

- 6453 DIELECTRIC HEMISPHERE-LOADED SCALAR HORN AS A GAUSSIAN-BEAM LAUNCHER FOR MICROWAVE EXPOSURE STUDIES. (Eng.) Neelakantaswamy, P. S. (Electronics Section, Sch. Applied Sciences, Univ. Science Malaysia, Minden, Penang, Malaysia); Hong, F. C. *IEEE Trans Microwave Theory Tech* 27(9): 797-799; 1979. (14 refs)

A new type of Gaussian-beam launcher for producing a focused microwave exposure field in biologic experiments for selective partial-body irradiation is proposed. The launcher is formed by placing a dielectric hemisphere (instead of a full sphere) at the aperture end of a corrugated circular waveguide (scalar horn) that supports a balanced hybrid ( $\text{HE}_{11}$ ) mode. This enables a reduction in the path length of the ray in the lens-medium, and hence the spherical aberration effects are relatively minimized. Also, by using a hemisphere instead of

a full sphere, the launcher structure become lighter and smaller. An X-band launcher was designed and fabricated based on the theoretical results for an aperture edge taper of 25 dB at a frequency of 9.5 GHz. The desired spot size at a distance of 6 cm along the optical axis from the lens was taken as 28 degrees, corresponding to a spot diameter of 5 cm at a distance of 6 cm from the lens along the optical axis. The sphere radius was calculated to be about 4.25 cm. The dielectric hemisphere was made with paraffin wax and was supported at the horn aperture by polystyrene foam. The spherical aberration function calculated for this lens is presented as a function of the equivalent aperture radius normalized with respect to the free-space wavelength. For comparison, the aberration function resulting from the use of a full sphere is also illustrated graphically. A considerable reduction in the aberration effects when the dielectric hemisphere is used as the lens is evident from these results. Near-field measurements were performed at a frequency of 9.487 GHz, and measured and calculated beam patterns at a distance of 6 cm along the optical axis from the lens are given. The results indicate that the test launcher produces a near-circular Gaussian beam in the proximity of the focusing lens. A simple design procedure can be used to calculate launcher dimensions for prescribed constraints (e.g., spot size) on the Gaussian beam.

- 6454 NON-IONIZING RADIATIONS. (Eng.) Ricketts, C. R. (MRC Industrial Injuries and Burns Unit, Birmingham Accident Hosp., Bath Row, Birmingham B15 1NA, England). *J Soc Occup Med* 28(4): 125-133; 1978. (4 refs)

The biologic and physical effects of various types of nonionizing electromagnetic radiation (e.g., UV, visible light, infrared [IR], microwave, and radio frequency radiation) are reviewed. The principal effect of nonionizing electromagnetic radiation on man is general or localized heating. The detail of tissue damage varies with the different types of radiation. Microwaves and other radio frequency radiations generate heat at deeper tissue levels than IR; thus tissues that are not usually heated are damaged, as in the case of lens cataracts. Over the range from 30 to 30,000 MHz, the percent of incident energy absorbed in tissue increases from 10 to 60% while the depth of penetration, which is defined as the depth at which the energy is reduced to about one-third of its original intensity, decreases from 3 cm to 1 mm. Taking these two factors into consideration, the least favorable exposure frequency for living tissue is around 3,000 MHz, where 40% of the incident energy is absorbed and the depth of penetration is about 1 cm.

- 6455 AN EMPIRICAL FORMULA FOR BROAD-BAND SAR CALCULATIONS OF PROLATE SPHEROIDAL MODELS OF HUMANS AND ANIMALS. (Eng.) Durney, C. H. (Dept. Electrical Engineering, Univ. Utah, Salt Lake City, UT 84112); Iskander, M. F.; Massoudi, H.; Johnson, C. C. *IEEE Trans Microwave Theory Tech* MTT-27(8): 758-763; 1979. (7 refs)

An empirical relation for calculating approximate values of the average specific absorption rate (SAR) over a broad frequency range for any prolate spheroidal model is derived for E-polarized incident plane waves by using a combination of antenna theory, circuit theory, and curve-fitting. This formula provides a simple and inexpensive method for calculating the SAR for various spheroidal sizes between those of rats and humans. The formula satisfies the  $f^2$  SAR behavior at lower frequencies, the resonance characteristic at intermediate frequencies, the  $1/f$  behavior past resonance, and the dependence on the dielectric constant at the geometric optics limits. An expression for the resonance frequency ( $f_0$ ) in terms of the dimensions of the model is also derived, with the unknown expansion coefficients being determined by curve-fitting all of the data available in the second edition of the *Radiofrequency Radiation Dosimetry Handbook*. A comparison between values of  $f_0$  obtained from the formula with those obtained using the extended boundary condition method illustrates that the formula provides a quick and easy method for calculating the  $f_0$  with approximately a 5% error at most.

- 6456 EFFECTS OF LOCAL TUMOR HYPERTHERMIA ON THE GROWTH OF SOLID MOUSE TUMORS. (Eng.) Magin, R. L. (Dept. Electrical Engineering, Univ. Illinois at Urbana-Champaign, Urbana, IL 61801); Johnson, R. K. *Cancer Res* 39(11): 4534-4539; 1979. (36 refs)

Sensitivity to microwave-induced local tumor hyperthermia (43 C, 60 min) was investigated for eight different solid mouse tumors that were transplanted subcutaneously in the left flank of C3H/He, CD2F<sub>1</sub> (BALB/c x DBA/2F<sub>1</sub>), or B6D2F<sub>1</sub> (C57BL/6 x DBA/2F<sub>1</sub>) mice. The local tumor hyperthermia (LTH) microwave system consisted of a 2.45-GHz microwave source, a four-way power-dividing network and reflected power monitor, a temperature-controlled microwave power regulator, and small direct-contact microwave applicators (3.2-cm in diameter). The applicators were coupled to the tumor by enclosing the tumor in a bolus of muscle-equivalent dielectric material. The temperature at the center of the heated tumors was regulated to within  $\pm 0.1$  C, while the temperature uniformity within the tumor was  $\pm 0.5$  C. The temperature distribution measured in these tumors was: top, 43.5; center, 43.0 C; and bottom and edges, 42.5 C. Tumor growth inhibition (TGI) and tumor growth delay (TGD, the extra number of days needed by treated mice relative to control mice to reach an average tumor size of 1 cm<sup>3</sup>) were calculated. In general, LTH reduced the size and retarded the growth of treated tumors relative to controls for each of the tumors tested. Although slight increases in life-span were observed in several experiments, only 5/188 treated mice were cured. Of the eight tumors tested, colon carcinoma 26 and Lewis lung carcinoma were the least responsive, with TGIs of less than 35% and TGDs of about 1-2 days. Most of the tumors were moderately responsive to LTH; TGIs of 37-75% were observed following a single LTH treatment of B16 melanoma, mam-

mary carcinoma C3HBA, glioma 26, and mammary adenocarcinoma 16C. The most responsive tumors to LTH were M5076 ovarian carcinoma and colon carcinoma 38, with TGIs >62%. Colon carcinoma 38 and M5076 ovarian carcinoma were delayed by 6-13 days. The other tumors demonstrated intermediate responses, with 3- to 7-day TGDs. Multiple LTH treatments increased the response of all tumors both in terms of TGI and TGD. To compare the sensitivity of tumors to heat with their growth rates, the doubling times for tumors were averaged into three response groups based on the TGI and data for growth delay days. A poor-response group consisted of Lewis lung and colon 26 carcinomas. A moderate response group consisted of B16 melanoma, mammary adenocarcinomas 16C and C3HBA, and glioma 26. A good response group consisted of M5076 ovarian carcinoma and colon carcinoma 38. Records of median day of death showed no consistent difference between the life-spans of treated and control mice for the early metastasizing colon carcinoma 26, Lewis lung carcinoma, B16 melanoma, and mammary adenocarcinomas 16C and C3HBA. However, the rarely metastasizing glioma 26, colon carcinoma 38, and M5076 ovarian carcinoma all showed an increased life-span of about 20% following multiple LTH treatments.

6457 MICROWAVE EFFECTS IN *DROSOPHILA MELANOGASTER*. (Eng.) Dardalhon, M. (Section de Biologie, Institut Curie, 26, rue d'Ulm, 75005 Paris, France); Berteaud, A. J.; Averbek, D. *Radioprotection* 14(3): 145-159; 1979. (17 refs)

The effects of open-space microwave (MW) irradiation in the millimeter (73 GHz) and centimeter (17 GHz) range were examined in *Drosophila melanogaster*. Both the wild type strain Paris and the strain delta carrying melanitic tumors in the 3rd larval stage, in pupae, and in adults were used. Cooked baker's yeast was used as nutrient medium, and growth was monitored in an incubator (23 C without humidity control). The microwave apparatus included either a Klystron of the Varian VE 2103 type adjustable for the frequencies 69.5-75 GHz or a Klystron Sperry Rand SR 4419 type adjusted for 17 GHz. The power density was 100 mW/cm<sup>2</sup> at 73 GHz and 60 mW/cm<sup>2</sup> at 17 GHz. *Drosophila* eggs were treated at different stages of embryonic development, i.e., 2, 4, or 5 hr after laying. Larvae were treated at stage 1 (24-48 hr old), stage 2 (48-72 hr old), or stage 3 (72-120 hr old). Pupae were exposed on the 1st or 2nd day. Exposure times ranged from 2 to 3 hr. The unirradiated controls were kept at comparable conditions in all experiments. After 2 hr of exposure to 17 or 73 GHz, the hatching of irradiated eggs and their development were normal. In a few instances, there was a tendency to a decrease in survival of eggs treated at different stages; of larvae treated in stages 1, 2, or 3; and of pupae. However, this tendency was not always statistically significant. MW treatment did not induce teratologic changes in adults. Slight but statistically significant decreases in the incidence and multiplicity of tumors were observed in adult flies exposed to either 17-GHz or 73-GHz MW, and this effect seemed to be independent of the

embryonic, larval, and pupal stages at which irradiation was performed. This weak action of MW on tumorigenesis in *Drosophila* differs from that of ionizing radiation. It seems unlikely that thermic effects are responsible for the weak effect of MW on tumorigenesis because when larvae were exposed to temperatures of 29 or 30 C, tumor development was completely suppressed in a fraction of the adults without any change in multiplicity of tumors in the other fraction of adults. When 3-day-old wild-type females were irradiated with 17 GHz for 16 or 21 hr and crossed with untreated males, a 30% increase in fertility compared with untreated controls was observed. The viability and tumor incidence in offspring were not affected. Similar results were obtained when MW-treated males were crossed with untreated females.

6458 MARINE ELECTRIC FIELDS AND FISH ORIENTATION. (Eng.) Pals, N. (Lab. Comparative Physiology, State Univ. Utrecht, Jan van Galenstraat 40, Utrecht, Netherlands); Schoenhage, A. A. *J. Physiol. (Paris)* 75(4): 349-353; 1979. (15 refs)

Two geo-electric meters (GEM) for short-span measurements of direct current (DC) electric fields in the sea are described, and some results from a pilot study in the coastal waters of The Netherlands are presented. One device, known as GEM II, consists of a PVC tube containing two Ag/AgCl electrodes. One end of the tube is open, and the other is closed (for 0.5 sec) every 2.5 sec by means of a motor-driven valve. When the valve is closed, no electric current can flow through the tube, and only the electrode bias is measured. When the valve is open, both the electrode bias and the voltage gradient are measured. The electrode signals are fed to a differential DC preamplifier and to an alternating current (AC) amplifier. The (low frequency) signals are matched for recording on magnetic tape by means of a frequency modulating (FM) device. In the laboratory, the signals can be demodulated and displayed on an oscillograph; however, this device has its limitations as it measures only in one direction and gives only indirect information about the direction of the electric field. A three dimensional version of this system, the GEM III, was also constructed. In this module, one measuring electrode is situated in a PVC tube and is in connection with the surrounding seawater; the other electrode is placed in a central compartment. A valve system provides electric contact between this electrode and one of the other tubes. During a measuring cycle (6 sec), the valves open in a predetermined order so that with only one valve open the electrode bias is measured. When another valve is opened, both the electrode bias and the voltage gradient are measured. The signals are successively fed to a preamplifier, an FM modulator, a demodulator, and an oscillographic recorder. This GEM III device can be used in water to a depth of 200 m. The results of the pilot study performed in the Schelde estuary and in the Waddenzee were obtained with GEM II and GEM I (a unit with measuring electrodes that rotate around a vertical axis) devices. Local electric fields (up to 150  $\mu$ V/m) caused

by bottom structures and regional electric fields (up to 60  $\mu\text{V/m}$ ) due to electromagnetic processes were measured. Most of the recorded fields fell within the perceptive range of sharks (10  $\mu\text{V/m}$ ) and rays (1  $\mu\text{V/m}$ ).

- 6459 A BIOLOGICALLY ACTIVE COMBINATION OF MODULATED MAGNETIC AND MICROWAVE FIELDS: THE PRIORE MACHINE. (Eng.) Bateman, J. B. (Office Naval Res. Branch London, Box 39, FPO NY 09510). 26 pp.; 1978. [available through National Technical Information Service, Springfield, VA 22161, Document No. AD060 988]. (19 refs)

A generator, known as the Priore Machine, which produces a biologically active combination of modulated magnetic and microwave fields is described. It is claimed that the generator produces radiation that causes certain implanted animal tumors to regress and cures trypanosomiasis in certain laboratory animals. A review of the literature describing the generator and its biologic effects reveals that the biologic data are presented in careful detail while information on the generator is sparse and often contradictory. A review of the patent for the generator discloses that the active radiation emerges from a tube containing a rotating deflector upon which impinge, from several different sources, a stream of positive ions accelerated in a cyclotron, a beam of centimeter waves generated by a magnetron, and a magnetic field. Any or all of these may be chopped or modulated according to various patterns.

- 6460 STUDIES ON THE MICROWAVE-INDUCED AUDITORY EFFECT. (Eng.) Lin, J. C. (Dept. Electrical and Computer Engineering, Wayne State Univ., Detroit, MI 48202). 74 pp.; 1979. [available through National Technical Information Services, Springfield, VA 22161, Document No. BES-1]. (35 refs)

A thermoelastic theory of acoustic wave generation in spherical models of the mammalian head exposed to rectangular pulses of microwave energy is presented. It was shown that the distribution of absorbed energy inside the head is approximately spherically symmetric for many combinations of size and microwave frequency. By taking advantage of the symmetry of the absorption pattern and assuming that heat conduction does not occur within the short periods of time under consideration, it was possible to solve the thermoelastic equation of motion for the acoustic waves in the spherical head without shear stress under both stress-free and constrained-surface boundary conditions using boundary-value technique and Duhamel's principle. It was found that the fundamental frequency of sound generated inside the spherical head is independent of the frequency of the impinging microwave and the pattern of absorbed microwave energy distribution and is strictly a function of the size of the spherical head and the acoustic property of the tissue involved (velocity of sound). In addition to giving pressure and displacement amplitudes, the theory shows that there is an optimum

pulse width for the efficient conversion of microwaves to acoustic energy. For instance, computations indicated that the peak pressure generated in a cat-sized (3-cm radius) sphere exposed to 2,450-MHz energy is maximum around 2  $\mu\text{sec}$  and that it falls off rapidly for shorter pulse widths. Its decrease for longer pulse widths is characterized by some oscillatory behavior. A comparison of the thermoelastic theory of microwave auditory effect with experimental measurements revealed good correlation in terms of width of impinging microwave pulses, independence from microwave frequency and specific absorption rate distribution, frequency of sound, and threshold of sensation. The advantage of a small direct contact applicator in experiments involving electrophysiologic recordings simultaneous with microwave exposure was also demonstrated. This exposure technique eliminates the need for specially designed sensing devices and processing instrumentation necessitated by conventional microwave exposure techniques. Not only does the small direct contact applicator permit placement at different areas on the head to establish desired differences in absorbed energy distribution, but it also substantially reduces interference due to direct pickup of microwave artifacts by the recording electrode.

- 6461 A TECHNICAL REVIEW OF THE BIOLOGICAL EFFECTS OF NON-IONIZING RADIATION. (Eng.) McRee, D. L., Chairman (ad hoc Working Group, Office Science and Technology Policy). 41 pp.; 1978. [available through National Technical Information Services, Springfield, VA 22161, Document No. PB 290 166]. (9 refs)

A review of the present state of knowledge of the biologic effects of nonionizing electromagnetic radiation is presented along with recommendations for current research needs in this area. The review includes radio frequency radiation (RFR) from 1 Hz to 300 GHz and electric and magnetic fields associated with both direct current and alternating current high voltage transmission lines (HVTL). Research in the past 5 yr has indicated that some biologic systems exhibit responses to RFR at exposure intensities that were previously considered to be too low to produce detectable alterations (1-10  $\text{mW/cm}^2$ ). The extent to which RFR-induced perturbations actually compromise living systems has not been determined, nor are the RFR conditions necessary to produce an observed alteration well defined. Although present evidence for the effects of RFR on the nervous system and on the reticuloendothelial system, including immunologic processes, is scanty, biomembrane alterations appear to be involved in many of the reported effects. Much less research has been done on the effects of HVTL fields, and biologic systems have not been adequately tested to determine if deleterious interactions do occur. It is difficult at present to develop meaningful guidelines for exposures due to insufficient data covering exposure conditions such as frequency, waveform, and exposure duration. In conjunction with biologic effects research, it is essential to in-

## CURRENT LITERATURE

*Biological Effects of Nonionizing Electromagnetic Radiation IV(3), March 1980*

corporate long-term, low-level studies, mechanisms of interaction studies, and to develop appropriate instrumentation and dosimetric techniques. Areas of biologic effects research that are considered highest priority based on current knowledge and recent research include the nervous system, reticuloendothelial system, membrane structure and function, and teratologic and developmental effects.

- 6462 ELECTRICAL PARAMETER VALUES OF SOME HUMAN TISSUES IN THE RADIOFREQUENCY RADIATION RANGE. (Eng.) Penn, J. W.; Bell, E. L. (Aerospace Medical Div., USAFSAM, Brooks Air Force Base, TX 78235). 21 pp; 1978. [available through National Technical Information Services, Springfield, VA 22161, Document No. SAM-TR-78-38]. (12 refs)

Electrical parameter values of some human tissues in the radio frequency range of 10 to 10,000 MHz are reported. Curves of conductivity and dielectric constant as a function of frequency are given for muscle, skin, dura, brain, blood, cerebrospinal fluid (CSF), and fat-bone-yellow bone marrow. Because of the scarcity of measured values (particularly at the high and low ends of the frequency range, where conductivity and dielectric constant vary rapidly), the curves for tissues of medium or high water content are drawn in proportion to the curves for muscle, for which relatively extensive data exist. Values extracted from these curves give reasonable estimates of the interrelationships among various tissues over the frequency range of interest. Values of conductivity (at a frequency of 800 MHz and a temperature of 37 C) extracted from appropriate curves for brain, CSF, dura, bone, fat, skin, muscle, blood, and yellow bone marrow are 0.96, 1.74, 1.23, 0.096, 0.096, 1.23, 1.45, 1.60, and 0.096 ohm/m, respectively. The corresponding dielectric constants for these tissues are 33.76, 79.47, 45.64, 5.61, 5.61, 45.64, 51.27, 61.52, and 5.61, respectively.

- 6463 SEAFARER: IMPACTS AND STUDIES OF THE EXTREMELY LOW FREQUENCY COMMUNICATION SYSTEM (A BIBLIOGRAPHY WITH ABSTRACTS). (Eng.) Lehmann, E. J. (NTIS, Springfield, VA 22161). 185 pp.; 1979. [available through National Technical Information Services, Springfield, VA 22161, Document No. NTIS/PS-79/0025]. (177 refs)

Studies are cited covering the search period 1964 to January 1979 of U.S. government-funded research on the Navy's global communication system that employs extremely low frequency (ELF) radio waves. This system, was previously called Sanguine, has been given the name Seafarer. The bibliography is divided into four parts. The first covers the biologic effects of ELF radiation on humans, animals, plants, and ecosystems. The second part presents research on equipment, performance, feasibility, design, and transmission. The last two sections cite surveys for the Sanguine antenna in Texas and Michigan. This updated bibliography con-

tains 177 abstracts, 11 of which are new entries to the previous edition.

- 6464 PARENTAL RADIATION AND DOWN'S SYNDROME, WITH PARTICULAR ATTENTION TO IONIZING RADIATION AND RADAR. (Eng.) Cohen, B. H. (Johns Hopkins Univ., Sch. Hygiene and Public Health, Baltimore, MD 21205). 360 pp.; 1976. [available through National Technical Information services, Springfield, VA 22161, Document No. AD-A061593]. (232 refs)

In order to confirm or reject previous findings suggesting an association between Down's syndrome and maternal exposure to fluoroscopic and therapeutic radiation or possibly between this disease and paternal exposure to radar, a replication of the original study was performed on parents of a current series of 300 Caucasian Down's syndrome cases and controls (born in 1962-1968 and 1945, respectively). In addition, validation of military service and radar exposure through a search of government records on all original and current series fathers (involving 791 cases, controls, and new matches) was performed along with a chromosome study of 162 radar-exposed and unexposed fathers (159 with successful cultures) from both series. In contrast to the original findings, data for the current series showed no difference in medical radiation exposure between case and control mothers (or fathers). Data for the current series also indicated no difference in radar exposure between case and control fathers. Even when the original and current series were combined, no significant differences were observed between case and control fathers with respect to radar exposure or military service. While more chromosome aberrations were seen in radar-exposed than in unexposed fathers for the two series combined, excesses in the particular types of deviants observed (gaps and single chromatid breaks) can be attributed to technical error; thus, the cytogenetic findings may not be a reliable indicator of chromosome fragility associated with microwave exposure. More definitive, preferably longitudinal studies are required for confirmation or rejection of such a possible hazard.

- 6465 HEMATOLOGIC EFFECTS IN MICE EXPOSED TO PULSED AND CW MICROWAVES. (Eng.) Ragan, H. A.; Phillips, R. D. (Experimental Pathology Section, Biology Dept., Battelle Pacific Northwest Lab., Richland, WA 99352). 24 pp.; 1979. [available through Office of Naval Res. Annual Report, Contract No. N00014-76-C-115]. (9 refs)

Hematologic and immunologic effects of continuous wave (CW) and pulsed wave (PW) microwave radiation were studied in female Swiss Webster mice under well controlled and defined exposure conditions. For each study, 16 mice were randomly assigned to two groups: 8 for microwave exposures and 8 for sham exposures. In some experiments, mice were exposed in the far field of an anechoic chamber to 2,880-MHz PW microwaves (2.3- $\mu$ sec pulses, 100/sec) for 3-7.5 hr/day, with the total exposure time



ranging from 60 to 360 hr. Five studies were performed at average power densities of 5 mW/cm<sup>2</sup> and four at 10 mW/cm<sup>2</sup>. The mean specific absorption rates were 2.25 mW/g at 5 mW/cm<sup>2</sup> and 4.50 mW/g at 10 mW/cm<sup>2</sup>. An additional group of mice was exposed to 2,450-MHz CW microwaves at a power density of 5 mW/cm<sup>2</sup>. In two of five studies with 5-mW/cm<sup>2</sup> PW microwaves, there was a significant ( $p < 0.01$  and  $< 0.05$ ) increase in bone marrow cellularity compared with sham-exposed groups. Significant differences were occasionally seen in erythrocyte, leukocyte, and platelet measurements from microwave-exposed groups, but these effects were not consistently observed. The only effect in mice exposed to 5-mW/cm<sup>2</sup> CW microwaves was a reduction in reticulocyte concentration ( $p < 0.02$ ). During one of four exposures to 10-mW/cm<sup>2</sup> PW microwaves, mean bone marrow cellularity was reduced ( $p < 0.02$ ) in the microwave-exposed mice; in another group the concentration of circulating lymphocytes was increased ( $p < 0.05$ ). During only one exposure (10 mW/cm<sup>2</sup> for 360 hr) was any effect on serum proteins noted (reduction from  $5.6 \pm 0.36$  g/deciliter [dl] in sham-exposed mice to  $5.1 \pm 0.29$  g/dl in exposed mice). This was due to a decrease in alpha and beta-globulins, with no effect on albumin or gamma-globulin concentrations. No effect on bone marrow hematopoietic colony-forming units (CFU) was noted after exposure to 5-mW/cm<sup>2</sup> PW microwaves. However, after one of four exposures to 10-mW/cm<sup>2</sup> PW microwaves, there was a significant ( $p < 0.05$ ) increase in CFU-agar colonies. No significant effects of 10-mW/cm<sup>2</sup> microwave exposures were detected on assays of in vivo and in vitro cell-mediated immune functions. No exposure-related histopathologic lesions were found on examination of several tissues and organs.

6466 QUANTIFICATION AND MEASUREMENT OF INTERNAL ELECTROMAGNETIC FIELDS INDUCED IN FINITE BIOLOGICAL BODIES BY NONUNIFORM ELECTROMAGNETIC FIELDS. (Eng.) Chen, K. M. (Div. Engineering Res., Michigan State Univ., East Lansing, MI 48824). 13 pp.; 1978. [available through U.S. Army Res. Office Final Report, Grant No. DAAG 29-76-G-0201, Project No. P-13448-L]. (12 refs)

A tensor integral equation method was developed to quantify the internal electromagnetic fields (EMF) induced in finite, heterogeneous biologic bodies by nonuniform impressed EMF. An experimental study was also conducted to develop and study implantable EMF probes that can be used to measure the internal EMF induced in simulated biologic bodies. Additional studies were performed to investigate induced EMF inside the human body, EMF local heating for hyperthermic cancer therapy, and the interaction of near zone fields of an antenna with the human body. Using the tensor integral equation method to quantify the internal electric field and the specific absorption rate (SAR) of EMF induced inside human bodies exposed to EMF of up to 500 MHz, it was found that the induced SARs inside the body depend strongly on the body geometry and the frequency and polarization of the incident EMF. In many cases, hot spots were induced in narrow

regions of the body such as the neck, legs, and arms. To verify the theoretical results, an experimental study was conducted to directly measure the induced electric field inside a phantom model of man with a noninterfering implantable electric field probe. The section of lead wires adjacent to the probe was constructed with two series of lumped resistors (3,000 ohms each) to minimize the current induced on the lead wires by a strong electric field that is perpendicular to an irradiated conducting body surface. The probe itself was made from a zero-bias microwave diode. Qualitative agreement was obtained between the theory and the experiment. The main cause of discrepancy between theory and experiment appeared to be due to numerical inaccuracy, which could only be improved by subdividing the body into many more subcells. A study investigating effective methods of inducing EMF hyperthermia in internal tumors in animals and humans is also described, with references provided for the published results.

6467 URSI PURSUED: MILLIMETER WAVE BIOPHYSICS. (Eng.) Bateman, J. B. (Office of Naval Res., Branch Office, London, England). pp. 404-409; 1978. [available through European Scientific Notes, ONRL Report No. ESN 32-12]. (20 refs)

The theories and experiments presented at the URSI symposium on millimeter wave biophysics that dealt with the construction of simple biologic systems for displaying the effects of weak nonionizing radiation are reviewed. Theories that were presented included: 1) supramolecular sensitive domains in biologic systems that can be raised by metabolic energy to a single coherent metastable vibrational state; 2) the resonance frequency of this domain may be in the range of 100-1,000 GHz; 3) the supply of microwave energy at the resonance frequency above a critical rate will generate the coherent state within the sensitive domain and thus modify the behavior of the system; 4) the microwave action spectrum is highly frequency-specific, having the character of one or more resonance curves, possibly damped by mode-softening occasioned by long-range dipole-dipole interactions; 5) the dose-response relation will tend to a step function at a critical level of absorbed energy; 6) the response to microwave stimulation is a highly specific property, indicating that sensitive test systems will be required; and 7) long-range coherent interactions involving more than one enzyme system may give rise to slow chemical and electric oscillations. Three presentations that offered new information on dielectric and microwave spectroscopic properties of cell constituents included: 1) experiments with microwave dispersion in the dog brain over 0.11-7.0 GHz, with the results analyzed in terms of free and bound water in a suspension of nonconducting spheres; 2) an extremely sensitive method for microwave spectroscopy of transparent materials in which a split laser beam is used to detect changes in the refractive index that are produced by microwave absorption; and 3) the scanning and computer processing of the data from various dense aqueous solutions and suspensions of biologic materials

at 0.5-GHz intervals over the range of 26.5-90.0 GHz. Experiments were also discussed that dealt with the use of lysogeny as a state possibly inducible by microwaves, the incorporation of a biologic temperature probe during irradiation of cells, and the simultaneous physicochemical and electrophysiologic study of the smallest available functioning domains of small or embryonic brains. Another presentation described an experiment in which ascites tumor cells were injected subcutaneously into mice after exposure for 20 min in vitro at controlled temperature to a 30-MHz field at 0, 5, or 10 V/cm. The effects, which were clearly distinguishable from the effects of heating, included a decreased percent of samples developing into tumors, an increased latent period, a progressive fall in the rate of volume increase, and an eventual regression. These changes were produced at the cellular level by low intensity irradiation; thus, this mouse assay provided an excellent method for biologic amplification. Although several worthwhile papers, theories, and experiments were presented at the URSI symposium on millimeter wave biophysics, little attempt was made to join theory with practice. An intensification of effort to detect microwave resonances and long-range interactions underlying some of the biologic phenomena is suggested.

6468 MICROWAVE IRRADIATION OF THE U.S. EMBASSY IN MOSCOW (REVIEW OF ITS HISTORY AND STUDIES TO DETERMINE WHETHER OR NOT RELATED HEALTH DEFECTS WERE EXPERIENCED BY EMPLOYEES ASSIGNED IN THE PERIOD 1953-1977). (Eng.) Committee on Commerce, Science, and Transportation. (U.S. Senate, 96th Congress, 1st Session). (Washington: U.S. Government Printing Office): 31 pp.; April, 1979. (7 refs)

Four studies to determine the health effects of microwave irradiation of employees at the American Embassy in Moscow between 1953 and 1977 are summarized. In 1965, the Medical Services Office of the State Department conducted an internal survey of the medical records of 139 employees and 268 dependents assigned to the Moscow Embassy. This internal survey plus a subsequent contract study, the "Moscow Viral Study," did not establish any genetic or other adverse biologic effects on employees and dependents that were attributable to microwave irradiation of the Embassy. However, the study was also unable to conclusively establish that no adverse effects were present. Another study, the "Project Pandora," was initiated in 1965 to investigate possible behavioral and bio-effects on primates irradiated with microwave signals simulating the exposure of Embassy employees in Moscow. To accelerate potential conclusions, the intensity of the microwave signal was set to the maximum useful capacity of the laboratory equipment then available, which yielded an exposure intensity of 4-5 mW/cm<sup>2</sup> compared with the average intensity of the Moscow signal that was 2-18  $\mu$ W/cm<sup>2</sup>. However, the Pandora primate study did not provide an acceptable answer to the above question because of experimental limitations

and design flaws. In 1976 a study was undertaken to determine if higher than average lymphocyte counts in Moscow Embassy personnel could be attributed to microwave irradiation of the Embassy personnel. Blood counts from Embassy subjects showed mean lymphocyte counts approximately 41% higher than those of a control group of foreign service personnel. However, the changes in the average lymphocyte count in the Moscow population did not correlate either in time or space with the exposure of individuals within the population to microwave irradiation of the embassy. A Johns Hopkins Foreign Service Health Status Study was conducted between 1976 and 1978 to analyze mortality and morbidity of Embassy employees and dependents assigned there between 1953 and 1976. This study found no evidence that the Moscow group experienced a higher total mortality or a higher mortality for any specific causes of death than a comparison group of nonirradiated subjects. However, morbidity data indicated two differences between the Moscow group and the comparison group. The Moscow male employees had a threefold higher risk of acquiring protozoal infections between the time of arrival at the Embassy and the time of last observation than did the comparison employees. Also, both men and women in the Moscow group had slightly higher frequencies of most of the common kinds of health conditions reported. However, these conditions represented a very heterogeneous collection, and it is difficult to conclude that they could have been related to exposure to microwave radiation since no consistent pattern of increased frequency in the group exposed to other than background microwave radiation could be found. Overall, no convincing evidence has been discovered that would directly implicate microwave exposure of Moscow Embassy employees in the causation of any adverse health effects.

6469 ELECTROMAGNETIC FIELDS IN BIOLOGIC MEDIA. PART II--THE SCAT PROGRAM. MULTILAYERED SPHERES, THEORY AND APPLICATIONS. Neuder, S. M. (Div. Electronic Products, BPA, Rockville, MD 20875). 17 pp; 1979. HEW Publication (FDA) 79-8072. (21 refs)

The theory and applications of a computer program (SCAT) for calculating the scattering and power absorption of radio frequency and microwave radiation by spherical lossy dielectric bodies exposed to linearly polarized plane wave fields are described. The irradiated body may be a homogeneous sphere or multilayered, spherically concentric regions of arbitrary radii. Each region can be made to simulate biologic tissue by assigning the appropriate dielectric properties. Induced fields and observed power density within these regions may then be calculated for preselected irradiation frequencies. Several applications of the SCAT program are discussed, and associated computer plots of fields and absorbed power are presented. These include the distribution of absorbed power density in the major plane of a 6.6-cm diameter homogeneous sphere exposed to a 3.0 GHz plane wave; the power absorption as a function of frequency in a 2.1-cm

diameter multilayered model of the hamster head; and the field intensity in a 3.3-cm and 8.0-cm radius homogeneous sphere at 2,450 MHz and 915 MHz, respectively, for probe measurement evaluation. From these plots it is seen that inhomogeneous systems exhibit discontinuities in the induced field and in the power deposition at the boundaries separating biologic tissue of different dielectric properties. Furthermore, spherical systems exhibit resonant properties depending on body dimensions relative to wavelength; these spherical body resonances give rise to internal hot spots. Although limited to applications where isolated spherical geometry is appropriate, the results may nevertheless be used to obtain quantitative estimates of the effects of relative body size, frequency, and dielectric properties on the total power absorption and on the internal distribution of absorbed power.

- 6470 ELECTROMAGNETIC FIELDS AND RELATIVE SAR PATTERNS IN BILAYERED BIOLOGICAL TISSUE EXPOSED TO A CIRCULAR APERTURE APPLICATOR (ABSTRACT). (Eng.) Tsiang, H. K. (Ph.D. dissertation, Univ. Washington, 1979); 184 pp. [available through *Diss Abstr Int B*, Order No. 7917654]. (0 refs)

The specific power absorption rate (SAR) was calculated for human tissues exposed to a direct- or indirect-contact microwave diathermy applicator having a circular aperture source with a TE<sub>11</sub> mode field distribution. The dielectric simulated fat-muscle tissue was bilayered. A Fourier-Bessel integral representation technique and a Gauss-Legendre Quadrature integration technique were used in the theoretical study and numerical computations, respectively. Limited experimental results were in agreement with theoretical predictions within a reasonable limit. The effects of varying aperture size and frequency on the induced normalized SAR and depth of penetration are considered. These studies provide a basis for designing an optimal applicator for therapeutic applications.

- 6471 A REVIEW OF EFFECTS OF MICROWAVE RADIATION ON BIOLOGICAL SYSTEMS. (Eng.) Cleary, S. F. (Dept. Biophysics, Medical Coll. Virginia, Virginia Commonwealth Univ., Richmond, VA 23298). In: *International Communications Conference. Conference Record*. (Boston, MA): Volume II, 79C H 1435-7 CSCB, 31.3.1-31.3.5; 1979. (35 refs)

Studies in the United States and in the USSR, Poland, and Czechoslovakia during the past 10 yr indicate previously undetected sensitivities of experimental animals to radio frequency (RF) exposures at intensities in the range of 1-10 mW/cm<sup>2</sup>. Reported effects on behavior, nervous tissue, and the immunologic and reticuloendothelial systems suggest specific sensitivities of mammalian systems to such exposure. Although experimental results do not correlate directly with effects reported to result from occupational exposure, the results are generally

consistent. Microwave- and other RF-specific exposure effects are demonstrated by qualitative and quantitative differences in response observed at equivalent levels of thermal stress. The assessment of risk of exposure to low-intensity microwave and other RF fields is complicated by the limited amount of data on effects of long-term or chronic exposure of animals or man, the complex nature of microwave and other RF energy absorption in the body, the detection of biphasic intensity and pulse repetition rate responses, and the lack of interaction mechanisms to account for low-intensity exposure effects.

- 6472 ELECTROMAGNETIC INTERFERENCE WORKSHOP: BIOLOGICAL ELECTRO-MAGNETIC INTERFERENCE (BEMI), MEDICAL WORKING GROUP SUMMARY, AND PLENARY SESSION IV SUMMARY "THE LAST, LAST WORD." (Eng.) Justesen, D. R.; Toler, J. C.; Arthur, M. G. In: *Proceedings of the 1978 Electromagnetic Interference Workshop held in Gaithersburg, MD, November 2-3, 1978*. Arthur, M. G., ed. (Boulder, CO: NBS): pp. 5-6, 38-41, 42-44; 1979. (0 refs)

Assuming that the earth's natural electromagnetic fields provide signals that not only enable avian navigation but also synchronize the mammal's biologic clocks, the coupling of artificially generated fields from power lines and from radio and television broadcasts could act as a source of biologic electromagnetic interference (EMI). It is pointed out that thoroughly defined and well documented instances of athermal, life-threatening EMI problems in man are essentially nonexistent, as are instances of life-threatening EMI problems in the area of medical electronic systems. Existing EMI standards for medical electronic systems are limited to the pacemaker standard developed by the Association for the Advancement of Medical Instrumentation (AAMI). Existing EMI standards for biologic systems are limited to safety levels of electromagnetic radiation with respect to personnel established by the American National Standards Institute (ANSI). Like the AAMI pacemaker standard, this standard was developed via a consensus procedure. Compliance is voluntary, and a 5-yr schedule for review, update, and/or withdrawal is used by ANSI. The acquisition and use of EMI environmental data was discussed. A complete description of the EMI environment would not be useful for establishing standards without full knowledge of radiation effects on the environment and systems. The Federal Communications Commission (FCC) rule-making policy, as it relates to consumer reaction and involvement, and the public's understanding and view of the term radiation was also discussed. Consumer reactions should represent a true cross-section of the consumers and not just a vocal minority. Accurate information should be disseminated to the public by organizations, the press, manufacturers, and FCC meetings.

- 6473 A REVIEW OF DIFFERENT STIMULATION METHODS. (Eng.) Herbst, E. In: *Electric Stim-*

*ulation of Bone Growth and Repair.* (New York: Springer Verlag): 1-13; 1978. (53 refs)

Various electrical stimulation methods used for experimental (animal) and clinical (human) bone growth and repair are briefly described. The following three techniques have been investigated in relation to electrically stimulated osteogenesis: direct current (DC) stimulation; stimulation with pulsed currents, pulsed voltages, and alternating currents; and electromagnetic field stimulation. In clinical studies, one investigator used stimulation with DC (10-20  $\mu$ A) in 24 nonunions and 5 congenital pseudarthroses (4 of the tibia and 1 of the clavicle). The cathode (stainless steel wire) was inserted into a small hole within the defect, and the anode consisted of a stainless steel skin electrode. In some cases, multiple cathodes were used. Complete union occurred in 15 nonunions and in 1 congenital pseudarthrosis of the tibia. For patients with nonunion of the tibia and femur, further immobilization after completion of 12 wk of electric stimulation was required to obtain complete healing. Another investigator used a combination of pulsed voltage stimulation and treatment with a Hoffman apparatus (maintains good external fixation) to treat 24 cases of crural fractures. The stimulator was attached to the frame of the Hoffman apparatus, and the insulated bone screws served as electrodes. The average time required to gain a certain stability was 30% lower in stimulated patients than in control patients. Skin irritation around the anode was observed during stimulation. Other investigators have reported over 100 cases of pseudarthrosis and spontaneous fractures treated with electromagnetically induced alternating current. The method used was invasive and based on internal fixation. Kuntscher nails or screws insulated from the osteosynthesis plate served as electrodes in this system. The pulsed magnetic field induced was about 30 Oe, and this field induced an alternating voltage at the electrodes of 0.3-0.5 V and a current of 1-2  $\mu$ A/mm<sup>2</sup>. No statistical evaluation of the results was reported.

6474 INFLUENCE OF MAGNETIC FIELDS ON GROWTH AND REGENERATION IN ORGAN CULTURE. (Eng.)

Gerger, H.; Cordey, J.; Perren, S. M. In: *Electric Stimulation of Bone Growth and Repair.* (New York: Springer Verlag): 35-40; 1978. (8 refs)

The effect of a magnetic field (MF) on the growth and regeneration of embryonic rat femurs was investigated. Embryos from SPF-albino rats in day 17 or 18 of gestation were cultured in vitro using a purely synthetic growth medium. All tests were performed with a field strength of 30 G and a frequency of 20 Hz applied during five equally spaced 60-min periods/day. In a first experiment, the femurs were oriented with their long axis parallel to the MF axis. The temperature of the culture medium was monitored daily with thermistors. In a second experiment, the cultures were protected against the heating effect of the MF coils, and the femurs were oriented with their long axis partly parallel and partly perpendicular to the MF axis.

In a third experiment, the distal epiphyses were cut half way across perpendicular to the long axis of the femur, and the test femurs were oriented so that the MF axis lay along the cut in the epiphyses; regeneration characteristics were then tested. In the first experiment, the difference in wet weight between test and control femurs was approximately 20% and was significant. However, the temperature measured in the MF test cultures was  $40.1 \pm 0.2$  C compared with a temperature of  $37.6 \pm 0.1$  C in control cultures. In the second experiment, no differences between wet or dry weights were observed between test and control femurs when the test and control media were held at comparable temperatures. In the third experiment, no differences in regeneration were observed between test and control femurs when the test and control media temperatures were comparable. There were no significant histologic differences between the test and control femurs in any of the three experiments. Overall, it is concluded that the organ cultures showed neither a positive nor a negative MF influence on the growth and regeneration of embryonic rat femurs. The significant differences in the first experiment were in all likelihood attributable to temperature differences. These results provide no basis for the clinical application of just the MF component of the Kraus-Lechner method.

6475 THERMAL DOSIMETRY: SOME BIOPHYSICAL CONSIDERATIONS. (Eng.) Cetas, T. C.; Connor, W. G.; Boone, M. L. In: *Cancer Therapy by Hyperthermia and Radiation. Proceedings of the 2nd International Symposium held in Essen, W. Germany, June 2-4, 1977.* (Baltimore: Urban and Schwarzenberg): pp. 3-12; 1978. (53 refs)

Biophysical considerations of thermal dosimetry when heterogeneous tissues are heated locally or regionally are discussed. To monitor temperatures within heated masses during localized hyperthermia trials, small thermometers must be used and biologic data suggest that thermal dose be recorded physically in terms of time at specified absolute temperatures to within 0.1 C. This limit of accuracy is possible if individual thermometers are calibrated and if sources of error are recognized. It is shown that needle-mounted thermometer probes must be inserted at least 4 mm into an object to avoid errors greater than 0.1 C. Nine thermometer probes that are under development for use in strong electromagnetic fields are listed. Two of these use thermistor sensors, one with microminiature integrated circuitry and the other with carbon-loaded PTFE leads. Resistance is the physical parameter sensed. Another five devices sense light intensity. The sensor is a liquid crystal in two of these, a liquid meniscus variation in one, an optically birefringent crystal (LiTaO<sub>3</sub>) in another, and a semiconductor optical absorption (GaAs) in the fifth. All use optical fibers as leads. Another probe with an optical etalon sensor and optical fibers for leads detects light wavelength changes. The ninth probe uses a fluid viscosity (orifice) sensor with dielectric tubing for leads to detect

fluid pressure difference. Noninvasive methods of determining temperature distributions in deep-seated heated regions are also being studied; these studies involve the use of the temperature dependence of the speed of sound in tissue as well as the use of a sensitive microwave radiometer to monitor the thermal radiation emitted at frequencies of about 1 GHz. Determination of the thermal dose implies knowledge of the temperature versus time profile throughout the volume of tissue being heated. Two or three probes implanted within the tissue may not provide sufficient information on thermal distributions. Thus, trials in phantom materials may be helpful in a semiquantitative manner for selecting heating configurations and for establishing how tissue characteristics (e.g., heterogeneous electrical resistivities or circulation patterns) affect the thermal pattern. Small volumes (1-10 cm<sup>3</sup>; e.g., mouse tumors) can be heated adequately by various methods and only a few watts of power are required to raise and maintain the tumor at hyperthermia temperatures. Thermal dosimetry and, in particular, thermometry are more troublesome for moderate volumes (10-100 cm<sup>3</sup>; e.g., human and large animal surface tumors) than for smaller ones. The required power level is on the order of 10-50 W, depending on the size of the mass and the mechanism of heat dissipation. Needle-mounted thermistors are routinely used to monitor temperatures in masses heated by 500-kHz current fields with little significant error. Large volumes and regional heating (greater than 100 cm<sup>3</sup>), which are applicable to many cases of clinical hyperthermia, are the most difficult problem in thermal dosimetry. Larger masses require more power (from 100 W to a few kW), enhancing the intensity of thermal gradients, especially if heat is conducted rapidly away from the region by massive blood flow. Tissue heterogeneities can cause thermal heterogeneities because of non-uniform power deposition or non-uniform cooling paths.

- 6476 REACTION OF CELL-MEDIATED IMMUNITY TO LOCAL HYPERTHERMIA OF TUMORS AND ITS POTENTIATION BY IMMUNOSTIMULATION--A REVIEW. (Eng.) Szmigielski, S.; Janiak, M. In: *Cancer Therapy by Hyperthermia and Radiation. Proceedings of the 2nd International Symposium held in Essen, W. Germany, June 2-4, 1977.* (Baltimore: Urban and Schwarzenberg): pp. 80-88; 1978. (56 refs)

Studies concerning the interaction of local microwave hyperthermia (LH) on tumors and cell-mediated immunity (CMI) are reviewed. An initial series of experiments on the effect of microwave hyperthermia, applied alone or in combination with nonspecific immunostimulators, on transplantable tumors revealed that whole-body microwave hyperthermia inhibited virus multiplication and influenced the course of experimental acute infections with herpesvirus (HSV<sub>1</sub>) and vaccinia virus. Daily whole-body microwave hyperthermia, applied immediately after inoculation and continued for 4, 8, or 12 days after infection, protected the animals from encephalitis development; the mortality rate was significantly lower in the hyperthermia-treated

animals than in the untreated controls (20-35% versus 95%, respectively). Whole-body microwave hyperthermia (2,450 MHz) inhibited the growth of sarcoma 180 in mice and lowered the mortality by about 60%. Because hyperthermia combined with Streptolysin S resulted in a significantly higher inhibition of tumor growth, it was concluded that immunotherapy may enhance the tumor-inhibiting effect of microwave hyperthermia. This was confirmed in a series of experiments on the combined effects of microwave hyperthermia with Poly I-Poly C and/or mouse interferon on the growth of sarcoma 180. All three factors resulted in lowered mortality (by about 50%), tumor regression (16/24 tumors), and reduction of the tumor mass (from 1,361 to 575 mg). Since neither combination of LH with Streptolysin S or Poly I-Poly C and/or interferon led to total cure of sarcoma 180, rats bearing Guerin epithelioma, a poorly metastasizing tumor with high infiltration by macrophages, were treated with 2,450-MHz LH (43 C) in combination with known nonspecific immunostimulators purified Streptolysin S and *Corynebacterium parvum*. The results summarized to date indicate that LH applied three times for 1 hr on the 3rd and/or 5th wk after tumor implantation resulted in an increase in tumor temperature from about 30 C to 43 C over 6-7 min. The temperature of muscles below the tumor did not exceed 41 C, while rectal temperature and the temperature inside the abdominal cavity did not exceed 38 C. The best results were obtained when tumors were heated on both the 3rd and 5th wk, although no total tumor cures were observed. Immune system monitoring was performed 8 wk after tumor implantation. Inhibition of tumor growth by LH and immunopotentiators was accompanied by stimulation of CMI. Increased cytotoxicity of spleen cells and peritoneal macrophages from LH-treated rats to cultured Guerin tumor cells and high reactivity of lymphocytes to mitomycin-inhibited tumor cells indicated specific stimulation of the T lymphocyte systems by heat-suppressed tumor cells *in vivo*. It is suggested that the population of suppressed tumor cells that survives LH because of nonuniform heating of tumors may be a very important factor in the stimulation of immunologic systems and in the inhibition of both the primary tumor and its metastases. In view of the immunostimulation by intensive LH, great care should be taken in combining heat treatment with either x-rays or cytostatic immunodepressants. It is concluded that further study of the stimulation of the immunologic systems by LH and of hyperthermia as a simultaneous selective killer of cells and an immunopotentiator is needed.

- 6477 RADIATION AND HYPERTHERMIA. (Eng.) Johnson, R. J. In: *Cancer Therapy by Hyperthermia and Radiation. Proceedings of the 2nd International Symposium held in Essen, W. Germany, June 2-4, 1977.* (Baltimore: Urban and Schwarzenberg): pp. 89-95; 1978. (39 refs)

The use of hyperthermia (HT), alone or in combination with radiation, for cancer therapy is reviewed. In addition to whole-body HT, water-bath

# CURRENT LITERATURE

HT, and hyperthermic perfusions of the extremities or bladder, regional HT using radio frequency (RF) currents is possible. RF current HT may provide a good heat distribution for some tumors since the surface electrodes can be shaped to obtain the desired distribution. Limitations of this method include fall-off of heat with increasing depth and excessive surface heating. Localized current fields employing 500 kHz and either noninvasive external electrodes or implanted needle electrodes have been used in five patients with recurrent tumors. HT was applied without radiation therapy (RT), and tumor regression was reported using temperatures of 44 C. In another study, six patients were treated with RT at the end of a 45- to 60-min heating period. Heat was applied initially using hot air; later, microwaves were used. Skin temperatures of 42-48 C were measured during microwave heating. Good tumor regression with an increase in normal skin response was reported. In a pilot study, multiple cutaneous metastatic human tumors were treated with either high dose fractions of RT alone or with lower dose fractions of RT in combination with HT (41.5-42 C). Heat was applied using either 2,450- or 915-MHz microwaves. Either dielectric or air surface cooling was developed for use with 915-MHz HT to obtain an improved heat distribution at depth. The results suggested that a thermal enhancement ratio for the tumor of 1.2-1.3 could be obtained. Skin scoring data for the normal tissue thermal enhancement ratio was inadequate to obtain a therapeutic ratio; however, it was apparent that the normal skin response was increased by the addition of post-RT HT. A cooperative group protocol has been developed to establish a therapeutic ratio for post-RT heating of tumor and skin to 41.5-42 C using a heat period of 2 hr and three RT fractions (with 72 hr between each fraction to avoid the possibility of thermal tolerance). Opposing field pulsed microwave units are being developed that will be suitable for heating buccal lesions; one applicator is used inside the mouth and another large applicator is used externally. Frequencies from 433 to 915 MHz will be selected to achieve optimum thermal dosimetry. Radio frequency and microwave applicators may have specific tumor sites for optimum application, however, a considerable effort must be made to obtain accurate thermometry during heating periods and to obtain thermal isodose lines. The future of hyperthermia and/or radiation techniques for cancer therapy will depend on several factors: the development of hyperthermia techniques, the investigation of both normal and tumor tissue responses to hyperthermia, and the application of currently used techniques and available physiologic data in the design of new clinical protocols.

- 6478 ON A NEW PHYSICAL PRINCIPLE FOR SELECTIVE LOCAL HYPERTHERMIA OF TUMOR TISSUES.  
(Eng.) von Ardenne, M. In: *Cancer Therapy by Hyperthermia and Radiation. Proceedings of the 2nd International Symposium held in Essen, W. Germany, June 2-4, 1977.* (Baltimore: Urban and Schwarzenberg): pp. 96-104; 1978. (22 refs)

A new radio frequency procedure, the cancer multi-step therapy (CMT) selectotherm technique, is described that permits the supply of large heat quantities per volume unit into deep-seated, localized tumor tissues without causing thermal lesions in healthy tissues near or at the body surface. With the CMT technique, the supply of energy within the energized volume remains almost constant in the planes parallel to the body surface (x-y plane), and in the dual-system array (body section between two applicators), the energy supply on the z-axis normal to the body surface is reduced very slowly. The spatial homogeneity of the energy supply resulting from the CMT selectotherm technique is corroborated by measurements in a gelatin phantom. Similar phantom measurements demonstrated that the CMT technique creates a new physical situation with respect to the drop in energy supply versus growing penetration (AZ) into the body tissues. In one particular configuration, the drops in energy supply obtained in the center of the body for body layer thicknesses of 12, 16, 20, and 24 cm were 50, 33, 24, and 19%, respectively. With a single-system array and a thickness of 24 cm, the power supply would drop to 5%, and for a standard decawave apparatus with a coil section, the power supply would drop to 0.5%. In the case of the CMT selectotherm technique, the decrease in power supply obtained with growing depth into body tissues can be attributed to a reduced energy density in the superficial layers (by raster motion of the applicators) and to doubling the strength of the rotational magnetic field in the center of the body. Improved preconditions for achieving local hyperthermia in tumor tissues are created by building up local hyperthermia on the increased temperature level of a metabolism-induced whole-body hyperthermia (e.g., CMT spontaneous hyperthermia at 39.5 C) and by selectively increasing the thermal sensitivity of tumor tissue by creating a pH drop in tumor tissue and by decreasing the microcirculation (main step of the CMT concept). The main application of blood-stream and pH selective local hyperthermia is in treating late-stage primary tumors where the wide difference of blood streams and the pronounced pH difference between healthy tissue and tumor tissue contribute to the therapeutic selectivity. The application of pH-selective local hyperthermia alone is in treating early stage tumors and metastases. Compared with the host tissue, there is hardly any temperature increase in tumor tissue; however, the temperature of the host tissue itself becomes much increased. This is important in the case of metastases where it is often necessary to superheat a large portion of the body.

- 6479 METHODS OF INDUCING HYPERTHERMIA AND ITS MEASUREMENT. INTRODUCTION. (Eng.) Robinson, J. E. In: *Cancer Therapy by Hyperthermia and Radiation. Proceedings of the 2nd International Symposium held in Essen, W. Germany, June 2-4, 1977.* (Baltimore: Urban and Schwarzenberg): pp. 107-108; 1978. (0 refs)

Methods of inducing hyperthermia for the treatment

of cancer and other medical problems are briefly reviewed. Ultrasound (US) and electromagnetic radiation (EMR) have been introduced to overcome the problem of limited heat transfer through tissue, a difficulty associated with hot water hyperthermia. US is capable of penetrating soft tissues to depths required for cancer treatment, and it has the advantage of producing sharply focused beams capable of delivering greater heating at depth than near the surface. This advantage is counterbalanced, however, by the much larger absorption of US in bone than in soft tissue. In addition, transmission of US through air spaces, such as the lung, is very small. The technology exists to direct focused US beams to a select target volume in uniform soft tissue and to produce reasonably uniform heating. However, there are major problems with heating uniformity near bones and air spaces of any magnitude. EMR at frequencies ranging from a few kHz to several MHz has been used to treat medical conditions that respond to mild heating. One of the classic techniques uses radio frequencies (20-30 MHz) and capacitive plates placed on either side of the part to be heated. At these lower frequencies it is possible to heat deeply enough, but there is excessive heating of fat and some difficulty in controlling field shape. Radiative fields in the microwave range have been introduced to overcome some of these problems. With microwaves, limited penetration in wet tissue rather than selective heating of fat poses a problem. The depth of penetration depends on frequency and is much greater in fat than in wet tissues (26, 18, and 11 cm of fat and 9, 3, and 2 cm of wet tissue for microwave frequencies of 433, 915, and 2,450 MHz, respectively). Microwaves can be reflected from the boundary between fat and muscle layers; this effect results in standing waves and complex heating patterns. In addition, when microwaves impinge on a curved surface equivalent in size to their wavelength, both the amount and spatial distribution of energy deposited is size- and shape-dependent. Focusing of microwave energy in curved bodies can take place with an effective depth of penetration much deeper than predicted for simple plane objects.

6480 DEVICES FOR MICROWAVE HYPERTHERMIA.

(Eng.) Taylor, L. S. In: *Cancer Therapy by Hyperthermia and Radiation. Proceedings of the 2nd International Symposium held in Essen, W. Germany, June 2-4, 1977.* (Baltimore: Urban and Schwarzenberg): pp. 115-117; 1978. (0 refs)

Two types of microwave radiators that can be directly inserted into the target tissue for hyperthermic treatment are described. One, a microwave syringe for the direct injection of radio frequency and other microwave fields into deep tissues *in vivo*, consists of a subminiature rigid coaxial waveguide connecting to the generator at one end and terminating in a needle-like configuration that radiates the field at the other end. A coaxial guide is needed since the device has no low frequency cutoff. The radiator is obtained by open-

ending the outer conductor and having the inner conductor extend out beyond it for the proper length. Such a radiator is only effective when embedded in a lossy dielectric; only a small fraction of the power will be radiated into free space in this case because of the mismatch the element presents to the generator. However, it was possible to construct a needle radiator that effected a voltage standing wave ratio of less than 1.1 at 2,450 MHz when the radiator was embedded in a phantom material having the same dielectric permittivity and loss tangent as human muscle tissue. In these trials, the syringe consisted of a commercial 0.085-inch outer diameter coaxial Teflon-filled waveguide connected by standard connectors and cable to the microwave generator. At the radiating end, the inner conductor was extended out 0.67 inch to achieve the match mentioned above. The heating pattern effected by the microwave syringe was determined by placing the radiator between the halves of a styrofoam mold with a spherical cavity (radius of about 3 inches) filled with phantom material. Microwave power was injected for a short period, the mold halves were opened, and a thermograph photo of the mold was taken within a period short enough to eliminate the effects of thermal conduction. Typical results are illustrated for an injection of 50 W for 20 sec, demonstrating the feasibility of this type of device for a variety of applications and experimental uses. Waveguides of the type used here but with diameters an order of magnitude smaller are commercially available; these could be useful for microwave injection into very delicate tissue. Another microwave radiator constructed for insertion directly into the esophagus for hyperthermic treatment is also described. To fit through a standard Number 14 stomach tube, the radiating element and associated cable are less than 3 mm in diameter and are highly flexible. They are constructed integrally into a miniature coaxial cable, UG/174, with a braided outer conductor. This is a Teflon-filled, Teflon outer-covered coaxial cable with an outer diameter of 2.65 mm. The power attenuation of the cable over the 2 or 3 feet required through the stomach tube is insignificant. The radiator itself is a colinear array antenna formed by cross-connecting the inner and outer conductors of the cable at intervals. When the radiator is placed in a phantom material having the same dielectric permittivity and loss tangent as human muscle tissue at 2,450 MHz (and approximately the same thermal properties), more than 75% of the power is absorbed in the tissue simulator. The heating power effected by this device was determined by insertion into a section of polyethylene stomach tube that was then placed between the halves of a styrofoam mold with a cylindrical cavity (about 8 cm in radius) filled with the phantom material. Tests were performed with 2,450-MHz microwaves at a power of 50 W. The results indicate the feasibility of internal microwave hyperthermia through catheters such as stomach tubes. However, the results also indicate that hot spots were generated due to standing waves. A uniform cylindrical pattern could be obtained by mechanical motion or frequency sweeping. Attempts to resolve this problem by microwave design changes are also in progress.

- 6481 MICROWAVE HYPERTHERMIA APPLICATORS: DESIGN AND DOSIMETRY. (Eng.) Sandhu, T. S.; Kowal, H. S.; Johnson, R. J. In: *Cancer Therapy by Hyperthermia and Radiation. Proceedings of the 2nd International Symposium held in Essen, W. Germany, June 2-4, 1977.* (Baltimore: Urban and Schwarzenberg): pp. 118-121; 1978. (17 refs)

Two types of direct-contact microwave applicators designed to operate at frequencies of 915 and 2,450 MHz are described. Each applicator is essentially a square cross-section waveguide closed at one end and open at the application end. The waveguide is excited in the TE<sub>10</sub> mode, using a coaxial line probe antenna. To couple all of the incident power into the guide, the radiation resistance of the probe antenna is made equal to the characteristic impedance of the coaxial line, and the contribution of the TE<sub>10</sub> mode reactance to the total input reactance is adjusted to cancel the part of the input reactance contributed by all of the higher-order evanescent modes. One applicator, which is designed to operate at 2,450 MHz, can be used to deliver either microwaves alone or in conjunction with ionizing radiation. A prototype was designed, which was attached to a Picker 280-kV machine. The other applicator operates at 915 MHz, and its waveguide is loaded with low-loss dielectric material (dielectric constant = 6.0) to reduce the size of the waveguide (cross-section = 8-cm<sup>2</sup> side). The solid dielectric protrudes a few millimeters out of the conducting walls to avoid touching the skin. The applicator is further modified by attaching a plastic bag at the application end through which a dielectric liquid (2:1 mixture of ethylglycol and kerosene) is circulated to cool the skin surface. Dosimetric measurements of the temperature distribution for each applicator were made in vivo on pigs using copper-constantan 30-gauge thermocouple needles. For the 2,450 MHz applicator operating at a power output of 36 W, a steady state was reached in ~10 min. Maximum temperature was found at the skin surface. The temperature dropped by 3.5 C at a 2.83-cm depth. The temperature near the edge of the applicator parallel to the electric vector was about 1 C lower than at the center. The temperature near the other edge at right angles to the probe antenna remained within 0.5 C of the temperature at the center. Temperature measurements with the 915-MHz applicator were made with the dielectric liquid either circulating or not circulating. Net power transmitted to the tissue was maintained at 30 W. Steady state was reached in 10 min without dielectric circulation and in 12 min with circulation. Without the dielectric liquid circulating, the skin temperature was lower than that at a depth of 1 cm. Temperature dropped by 1 C at a depth of 2.83 cm. With the dielectric liquid circulating, skin temperature dropped considerably and was the same as that at 2.83 cm. Temperature peaked at about 1.5 cm, where it was 1.0 C higher. By manipulating the temperature of the dielectric liquid, it was possible to heat the tissue to a depth of 3 cm with a maximum deviation in temperature along the central axis of  $\pm 0.5$  C. Using a combination of the 915-MHz and 2,450-MHz applicators from opposite directions, a 4-cm thick slab

of muscle phantom material was irradiated, and temperature measurements were made along the central axis. The results indicated that this arrangement is capable of producing a clinically acceptable temperature distribution. In vivo studies involving these techniques for treatment are in progress.

- 6482 AN INTERSTITIAL DEVICE FOR MICROWAVE HYPERTHERMIA OF HUMAN TUMORS. (Eng.) LeBourgeois, J. P.; Convert, G.; Dufour, J. In: *Cancer Therapy by Hyperthermia and Radiation. Proceedings of the 2nd International Symposium held in Essen, W. Germany, June 2-4, 1977.* (Baltimore: Urban and Schwarzenberg): pp. 122-124; 1978. (0 refs)

An interstitial method for microwave heating of human tumors is described. The probes (either bipolar or unipolar,  $\leq 1$  mm in diameter) can be fitted into place by means of applicators of the type used in interstitial therapy. For the bipolar type, the microwave (or ultra-high frequency) current flows in the tissue between the inner and outer conductors of the coaxial cable. The current density can be shaped with a tapered dielectric coating to achieve good uniformity of dissipated power along the probe. Depending on the frequency, the active length of the probe can be varied in muscular tissue from about 5 mm at 2 GHz to 35 mm at 100 MHz. An advantage of the bipolar probe over the unipolar probe is that it can be used alone. With the latter type, the electric current flows between the inner conductors of different probes placed at some distance from each other; the outer conductors act only as shields. By using several probes of either the bipolar or unipolar type, it is possible to shape the region to be heated and to achieve a good uniformity of the temperature increase within it. Since both the bipolar and unipolar probes are "cold" (at temperature equilibrium with the surrounding medium), the temperature distribution obtained is much more uniform than the distribution that could be obtained with "hot" probes delivering the same power via heat conduction to the medium. In addition to the frequency of operation, the impedance and power output of the generator must also be considered. The impedance is a function of the probe diameter to the distance, length, and nature of the tissue to be heated. In muscle and similar tissue, probes 1 mm in diameter and 3 cm in length placed at a distance of about 1 cm from each other present an impedance of about 50 ohms for commercially available generators so that the matching of the probes (reduction of reflected power to zero) is straightforward. For a given configuration, the power necessary to reach the chosen increase in temperature is determined by the heat conductivity and and blood flow through the volume to be heated. As a rough indication, 3 W is enough to achieve a 6 C increase inside a cylinder 2.5 cm in diameter and 4 cm in length in muscular tissue. In this case, the equilibrium temperature is practically reached within 8 min, a time duration that could be de-



creased somewhat by applying a higher power such as 5 W for a few minutes. In the case of high blood flow, the power should be increased, with a corresponding decrease in the time necessary to reach the temperature equilibrium. A power of 10 W per probe is more than enough for any situation. A significant advantage of the above interstitial heating method is that the same set of probes can be used either to heat the tissue or to measure the temperature near each individual probe or in some volume surrounding them. This can be achieved through radiometric measurements. Another advantage to heating with the coaxial probes is the production of good localization of the heated region, without any over-heating, even at the probe location. Once practical experimental equipment for temperature measurement has been designed, measurements can be made in human tumors, completing one more step to producing a simple and reliable technique for clinical use.

- 6483 INDUCTION OF HYPERTHERMIA IN DEEP-SEATED TUMORS BY A SPECIAL MICROWAVE APPLICATOR. (Eng.) Mendecki, J.; Friedenthal, E.; Botstein, C. In: *Cancer Therapy by Hyperthermia and Radiation. Proceedings of the 2nd International Symposium held in Essen, W. Germany, June 2-4, 1977.* (Baltimore: Urban and Schwarzenberg): pp. 125-127; 1978. (2 refs)

A technique that may permit the treatment of certain deep-seated tumors by the introduction of coaxial microwave applicators into body cavities such as the bladder, colon, cervix, esophagus, etc. is described. In an initial experiment, the shape of a body cavity such as the esophagus was simulated by a cylindrical styrofoam container. Equal volumes (1.5 cm<sup>3</sup>) of animal muscle were arranged symmetrically at four equidistant points around the radiating antenna of a coaxial applicator placed in the center of the container. Temperature rise as a function of power and time was mapped using a 2,450-MHz microwave source, as was the spatial heat distribution. The results indicated that it is possible to reach the 42.5 C threshold temperature of interest in tumor cell destruction and that a fairly uniform temperature distribution (maximum variation of 1.5 C) could be maintained at a given radius. Directivity of heating was obtained by geometric modifications of the applicators, and in a second experiment, a coaxial applicator equipped with a semicylindrical (180 degrees) aluminum reflector was used in a simulated body cavity and the procedure of the previous experiment was repeated. Tissue cubes placed opposite the directive reflector of the applicator could be heated to a temperature of 43 C in 3 min using 25 W of power and could be maintained at this level for 20 min with only 4 W of power. The temperature at other points to the rear of the reflector showed only a slight increase. In a third experiment, an inflated rubber sphere with a coaxial cable placed at its center was inserted through a midline incision into the abdominal cavity of a live anesthetized rat whose intestines had been removed. The right half of the abdominal

wall was folded backward, increasing its thickness for the purpose of studying heat penetration. Application of 2,450 MHz resulted within 3 min to a temperature increase to 42 C, which was easily maintained. In contrast, the animal's oral temperature remained unchanged. In a final experiment, heat distribution when solid (muscle) tissue is heated directly was measured by implanting a 0.8-mm thick coaxial applicator into the thigh of a live rat. The temperature rose to 43 C at the applicator site within 5 min (2.5 W), while the other thermocouples registered about 1 C less for each 0.5 cm of distance. Similar results were obtained with coaxial applicators implanted into mouse mammary adenocarcinoma at a frequency of 2,450 MHz. Based on these experiments, a prototype of a coaxial applicator suitable for clinical use is proposed. This model would consist of a coaxial cable inserted into the center of an indwelling Foley catheter that could be inflated to conform to the anatomic space under treatment. Thermocouples affixed to the inflatable part of the catheter equidistant from the cable would permit monitoring the temperature at several points of the cavity wall, providing simultaneous readings within the heated malignant tumor and in the surrounding tissues.

- 6484 SIMULTANEOUS FAR-FIELD IRRADIATION OF MULTIPLE MOUSE TUMORS FOR MICROWAVE HYPERTHERMIA (Eng.) Cheung, A. Y.; Robinson, J. E.; McCulloch, D.; Samaras, G. M. In: *Cancer Therapy by Hyperthermia and Radiation. Proceedings of the 2nd International Symposium held in Essen, W. Germany, June 2-4, 1977.* (Baltimore: Urban and Schwarzenberg): pp. 128-130; 1978. (8 refs)

A microwave hyperthermia facility for the simultaneous far-field irradiation of several mouse tumors is described. The tumors were transplants of spontaneous mammary carcinomas on the flanks of C3H mice. Initially, local tumor heating in the free field with 2,450-MHz microwaves was accomplished by shielding the mouse within a tubular metal sleeve with the mouse tumor projecting into the heating field through a slot aperture in the cylinder. However, these small (1-cm) tumors were difficult to heat at 12-cm wavelengths and required relatively high power levels because of poor coupling. A strategy was then developed in which the tumors were encapsulated within a larger spherical mass ("microwave bolus") of phantom material. The microwave facility designed for this purpose incorporated a 3-kW, phase modulated, 2,450-MHz source (Gerling-Moore #4003) that was waveguide-fed to a ceiling-mounted standard gain horn antenna in a fully anechoic range (8 ft<sup>2</sup>). A parabolic surface intercepting the field axis 154 cm from the antenna was selected for the first experiments. Shielded mice were placed 25 cm (2 wavelengths) apart to minimize interactions between assemblies. Within a region 50 cm from the field central axis, up to 13 mice may be accommodated on the equal-power surface. Bolus spheres were formed within identical molds of dense styrofoam to replicate the standard bolus

# CURRENT LITERATURE

geometry. These molds also located the mouse shield and tumor relative to the bolus sphere, allowing optimum placement of the tumor in bolus. A 6-mm spacer of dense styrofoam extended the tumor away from the perturbed field region adjacent to the metal shield. Graphs of vertical and horizontal tumor temperature profiles indicated an overall temperature uniformity to within  $\pm 0.1$  C vertically and  $\pm 0.05$  C horizontally. Thus, heating uniformity to within 0.1 C may be achieved when tumors are encapsulated in a well-defined volume of tissue-equivalent material. The relatively large bolus volume tends to govern both temperature elevation and heating uniformity in the tumor, both of which are largely independent of tumor size between 0.5 and 1.5 cm. Phantom studies of heating at off-axis locations on an equi-power surface agree well with on-axis tumor heating. Those data suggest equivalent heating on the equi-power surface. The technique appears to be viable for simultaneous microwave hyperthermia of up to 12 tumors in this particular range configuration.

- 6485 PRODUCTION OF CONTROLLED HYPERTHERMAL FIELDS FOR CANCER THERAPY. (Eng.) Samaras, G. M.; Robinson, J. E.; Cheung, A. Y.; Prempre, T.; Slawson, R. G. In: *Cancer Therapy by Hyperthermia and Radiation. Proceedings of the 2nd International Symposium held in Essen, W. Germany, June 2-4, 1977.* (Baltimore: Urban and Schwarzenberg): pp. 131-133; 1978. (9 refs)

The designs of multiple-beam hyperthermia systems for obtaining enhanced deep heating without excessive heating of superficial tissue layers are described. For the first attempt at multibeam diathermy, a dual-beam, parallel-opposed set of TEM applicators was constructed for operation at 2,450 MHz. Microwave power was electronically time multiplexed between either of the two beams or off to a dummy-matched load. The treatment field between the apertures was bolussed to plane parallel geometry. The resultant thermal field with equal power and "on time" from each applicator was approximately parabolic along the propagation axis and uniform to within  $\pm 0.1$  C perpendicular to that axis. The apparatus was used to treat murine C3H mammary tumors on the flank of mice, with the core tumor temperature being controlled to within  $\pm 0.1$  C. Treatment at temperatures between 42 and 44 C resulted in progressively increasing delay in tumor regrowth and redoubling time for increased treatment time and temperature. Comparison of thermal sensitivity versus treatment temperature for water bath-heated tumors and microwave treated tumors showed the same slope but a lower sensitivity for microwave heating. A multiple-beam microwave thermotherapy system was also designed and was being tested at the time of this report. The system consists of a data acquisition and control section, a microwave power source, a coaxial microwave power switching sub-system, and miniature diathermy applicators. The system will allow control of superimposed microwave radiation patterns and resultant thermal field patterns by regulating the total energy radiated by each diathermy ap-

plicator, the total time that each diathermy applicator is radiating energy, the position of the multiple applicators, and the sequence in which each applicator is turned on and off. The microwave power source is designed to operate at 915 MHz, and it has external voltage-controlled power leveling and contains integral forward and reflected power monitors. Its output is passed through a triple-stub tuner to coaxial Transco Products solenoid switches where it is diverted to the miniature diathermy applicators. The current diathermy applicators are rectangular low-loss ceramic dielectric bars that are the size of an X-band waveguide (2.5 cm by 1.3 cm). A coaxial connector is mounted on each bar matching the applicator to a 50-ohm coaxial line. This multiple-beam system provides a method for obtaining enhanced deep heating without excessive heating of superficial tissue layers. Experiments with a dual-beam system resulted in enhanced heating effects that compared favorably with nonmicrowave heating. The computer-controlled multibeam system will be used to produce the controlled thermal fields necessary for hyperthermia cancer therapy.

- 6486 LOCAL HYPERTHERMIA BY MICROWAVE HEATING: EXPERIMENTAL DATA IN PIGS AND CLINICAL IMPLICATIONS. (Eng.) Kogelnik, H. D.; Prokosch, E.; Karcher, K. H.; Binder, W. In: *Cancer Therapy by Hyperthermia and Radiation. Proceedings of the 2nd International Symposium held in Essen, W. Germany, June 2-4, 1977.* (Baltimore: Urban and Schwarzenberg): pp. 136-138; 1978. (10 refs)

In vivo temperature measurements were performed in 9- to 10-wk old female German domestic pigs (28 to 30 kg) to determine the heat distribution following the application of decimeter-wave local hyperthermia in the gluteal regions (Philips DW 691: frequency, 433.92 MHz; wavelength, 69 cm; high frequency output, 200 W; power range, step 1-8). Optimal energy transmission was established by contact of the radiator with the skin. Heating periods of 10, 15, and 20 min were used with power steps 4, 6, and 8. Temperature measurements were performed before and immediately after microwave application using a NiCr-Ni coated thermocouple (0.5-mm diameter, measuring accuracy  $\pm 0.2$  C, reference temperature 0 C). Measurements were done at the site of skin contact with the radiator (center) and at distances of 1, 2, 3, and 5 cm around the center. An examination of the temperature increase after 15-min of heating (power step 8) up to 5-cm depth within a cylindrical volume of 10-cm diameter in the muscle mass of the gluteal region showed that a relatively homogeneous temperature elevation from the center to the periphery (5 cm around central axis) could be achieved within the first few centimeters of tissue depth. At a depth greater than 3 cm, the temperature increase was only about 1 C. The range of temperature increases after 15 min of heating was significantly higher with power step 8 compared to power step 6 (maximal temperature increases in the center at 1-cm depth, 4.6 versus 2.5 C; minimal temperature increases, 2.5 versus 1.1 C). With power step 4, there was a further

decline in temperature increases. Heating periods of 10 min (power steps 6 and 8) gave a maximum temperature increase at 1 cm depth of only 1.5 C. When the time was increased to 20 min (power step 8), there was a more homogeneous heat distribution in the deeper tissue layers in comparison with heating times of 15 min; however, the maximal temperature increases of 0.5 C (on the average) was obtained; at a depth of 4-5 cm, there was no longer a significant measurable difference. Because a time of about 4 min was needed to measure the entire volume in an experiment, the effective temperature increases were slightly higher than the ones recorded. These data show that with decimeter waves and heating periods of 15 min (power step 8), clinically useful temperature elevations can be obtained within the first few centimeters in depth and in a sufficiently large volume. Tumors with an impaired circulation and a low cooling capacity are likely to show higher temperature increases than normal tissue. Heating with decimeter waves can be performed immediately before or after radiation therapy without causing the patient any significant discomfort. The use of decimeter-wave therapy in combination with radiation therapy is currently being evaluated in cancer patients, e.g., with bulky recurrences on the chest wall or in the regional lymphatics, for superficial inoperable tumors, and for uncontrollable neck disease in patients with head and neck cancer.

6487 EFFECT OF MICROWAVE- OR ULTRASOUND-INDUCED HYPERTHERMIA COMBINED WITH IONIZING IR-RADIATION OF THE TESTIS OF RAT. (Eng.) Abadir, R.; Harman, J.; Fahim, M. In: *Cancer Therapy by Hyperthermia and Radiation. Proceedings of the 2nd International Symposium held in Essen, W. Germany, June 2-4, 1977.* (Baltimore: Urban and Schwarzenberg) pp. 214-215; 1978. (3 refs)

The effect of microwave (MW)- or ultrasound (US)-induced hyperthermia combined with ionizing radiation on the rat testis was investigated. Sixty sexually mature male rats were divided into the following six groups: controls (no treatment), US alone (3,000,000 Hz, 1 W/cm<sup>2</sup> for 5 min), MW alone (12.2 cm wavelength, 30 W for 5 min), x-ray alone (600 rads), x-ray plus MW (same parameters as above), and x-ray plus US (same parameters as above). A thermocouple was inserted in one testis for recording temperature during treatment, and the blood level of testosterone (TST) was measured by protein binding assay. Animals were sacrificed 60 days after treatment, and the testes were examined for weight and histology; the prostate was examined for weight. The temperature variations in the testes were nominal for the various modes of irradiation as follows: control = 35.0 ± 0.2 C, US = 37.6 ± 0.7 C, MW = 39.9 ± 0.4 C, and x-ray = 35.2 ± 0.2 C. A reduction in spermatogenesis was seen in all treated animals, with no difference between the testis punctured by the thermocouple and the contralateral one. The degree of disruption was scored as follows: moderate in rats treated by single modalities of radiation, severe in rats treated with x-rays and MW, and complete

in rats treated by x-rays and US. The percent of tubules affected by the various treatments was as follows: 0% for controls, 56% for US alone, 68% for MW alone, 72% for x-rays alone, 100% for x-rays and US, and 85% for x-rays and MW. Only the combination of US and x-rays resulted in a 75% reduction of the blood level of TST, an 80% reduction in prostate weight, and a significant reduction in the number of Leydig cells. An insignificant reduction in testicular weight was noted only in the x-ray-treated groups.

6488 COMBINATION OF RADIOTHERAPY, MICROWAVE HYPERTHERMIA AND CLOSTRIDIAL ONCOLYSIS ON EXPERIMENTAL MOUSE TUMORS. (Eng.) Dietzel, F.; Gericke, D.; Schumacher, L.; Linhart, G. In: *Cancer Therapy by Hyperthermia and Radiation. Proceedings of the 2nd International Symposium held in Essen, W. Germany, June 2-4, 1977.* (Baltimore: Urban and Schwarzenberg) pp. 233-235; 1978. (10 refs)

The antitumor effects of a triple combination of radiotherapy (RT), local microwave hyperthermia (LMHT), and clostridial oncolysis were compared with the effects of each modality alone in female NMRI mice bearing Harding-Passey melanoma transplanted as a neck tumor. LMHT was applied with an inductive Eddy current applicator (3.8-cm diameter) at 461 MHz with a Siemens generator. Mice receiving the triple combination first were irradiated with 2,000 R of x-rays followed immediately by 2 min of LMHT (40-41 C); 12 hr later, they received an intravenous injection (tail vein) of 10<sup>8</sup> spores of *Clostridium oncolyticum* s. butyricum. Animals receiving single modality treatment were treated with the same dose-schedules as above. The mean survival times for 49 untreated controls, 51 mice treated with RT only, 46 mice treated with LMHT only, 51 mice treated with *Clostridium* spores only, and 38 mice receiving a combination of the three treatments were 26.53 ± 0.87, 50.08 ± 1.64, 26.89 ± 0.89, 26.25 ± 0.84, and 69.03 ± 2.28 days, respectively. No animals were cured (150 days without relapse) in any treatment group with the exception of the triple combination group where the cure rate was 18%. The triple combination also caused the greatest reduction in tumor volume. Treatment with LMHT alone caused only a minor growth arrest after which tumors grew again unhindered.

6489 THE EFFECT OF HYPERTHERMIA ON HUMAN COLON CANCER XENOGRAPTS IN NUDE MICE. (Eng.) Osieka, R.; Magin, R. L.; Atkinson, E. R. In: *Cancer Therapy by Hyperthermia and Radiation. Proceedings of the 2nd International Symposium held in Essen, W. Germany, June 2-4, 1977.* (Baltimore: Urban and Schwarzenberg) pp. 287-290; 1978. (9 refs)

Three lines of human colon cancer xenografts in nude mice (NIH-Swiss, 4 wk old) were treated with either whole-body hyperthermia (WBH) or continuous wave (CW) microwave-induced local hyperthermia

(LH). WBH was achieved by confining metabolic heat in a 39.5 C ambient temperature environment with high humidity. LH was produced by dielectrically-loaded direct contact applicators (15 x 10 mm surface) operating at 2,450 MHz. The microwave source was an Elmed Microwave 150, which generates up to 50 W of CW microwave power. By switching the microwave power either to the applicator or to a matched load, a tumor core temperature of  $42.5 \pm 0.1$  C was maintained. Tumor core temperature was measured by a 0.13-mm copper/constantan thermocouple placed through the tumor with a 25-gauge needle and oriented perpendicularly to the direction of the electromagnetic field. Mice were randomized into treatment groups of four to six animals when tumors had reached a palpable size (about 60-100 mg). WBH at rectal temperatures of 40.0 C for 45 min reduced the survival of mice to 50% in comparison with untreated controls, but was ineffective in controlling tumor growth. However, LH (3 x 60 min at 42.5 C) produced a complete regression rate of 50% for tumor line BE, which was 100% sensitive to the antitumor nitrosourea methyl-CCNU at a single intraperitoneal dose of 18 mg/kg. Only transient regressions were observed in tumor line CA after treatment with either LH or methyl-CCNU, and line HT was completely resistant to both LH and methyl-CCNU. No potentiation of methyl-CCNU by concomitant LH (42.5 C for 60 min) was observed in any of the three colon tumor xenografts. All studies with LH were performed on mice bearing bilateral tumor implants, and growth patterns of untreated tumors did not differ from those obtained in untreated mice. Thus, LH did not appear to enhance host immunogenicity. These findings support a role for LH in the treatment of colon cancer that is often resistant to either chemotherapy or conventional radiotherapy.

ference. Four of the patients had previously received radiotherapy, and one had received combination chemotherapy and immunotherapy. The first patient (57 yr old) presented with a squamous cell carcinoma of the base of the tongue, recurrent and with widespread metastases. After receiving one noninvasive LCF treatment (44 C, 90 min), good pain palliation and tumor regression were observed. However, the patient died of cardiopulmonary arrest 6 days after treatment. The second patient (77 yr old) presented with advanced local disease at the base of the tongue. Good pain palliation and tumor regression for 1 mo were achieved after one noninvasive LCF treatment (44 C, 60 min). The patient died of progressive disease 15 wk after treatment. The third patient (76 yr old) presented with a rapidly regrowing 3-cm mass in the floor of the mouth. Two courses of invasive LCF using biplanar interstitial implants (43 C, 30 min; 44 C, 25 min) were given over a 2-wk period. Pain relief with complete tumor regression was seen after the second treatment. The patient is alive with no evidence of disease 14 mo after treatment. The fourth patient (43 yr old) had large-cell undifferentiated carcinoma of the lung that was metastatic to the axilla and supraclavicular and hip regions. Two noninvasive treatments (42 C, 34 min; 43 C, 32 min), separated by 7 days, produced local pain palliation. The patient died of progressive disease 27 days after treatment. The last patient (52 yr old) had a history of extensive recurrent malignant melanoma of the right leg, metastatic to the right thigh and groin region. Six lesions in a disarticulated hip stump region were treated with eight noninvasive LCF treatments (42-44 C, 10-36 min) over an 8-day period. Slight regression and pain palliation were achieved. The patient is alive with disease and is currently undergoing chemotherapy.

6490 CLINICAL USE OF RADIOFREQUENCY CURRENT IN ORAL CAVITY CARCINOMAS AND METASTATIC MALIGNANCIES WITH CONTINUOUS TEMPERATURE CONTROL AND MONITORING. (Eng.) Sternhagen, C. J.; Doss, J. D.; Day, P. W.; Edwards, W. S.; Doberneck, R. C.; Herzon, F. S.; Powell, T. D.; O'Brien, G. F.; Larkin, J. M. In: *Cancer Therapy by Hyperthermia and Radiation. Proceedings of the 2nd International Symposium held in Essen, W. Germany, June 2-4, 1977.* (Baltimore: Urban and Schwarzenberg): pp. 331-334; 1978. (1 ref)

The use of a localized radio frequency current field (LCF) technique with continuous automatic temperature control for the treatment of five patients with oral cavity carcinomas or metastatic malignancies is reported. The shape of the LCF fields was determined by electrodes of an invasive (internal) or noninvasive (external) type. An error signal modulated the radio frequency generator to minimize any variation from the set-point temperature so that temperature at the control location in the treatment volume (hot-test point) was held to within  $\pm 0.2$  C of the specified level during treatment. A frequency of 500 kHz was used to enable accurate temperature monitoring without inter-

6491 CLINICAL TRIAL WITH HYPERTHERMIA AND RADIOTHERAPY: CUTANEOUS CANCERS AS A MODEL SYSTEM. (Eng.) Kim, J. H.; Hahn, E. W.; Tokita, N. In: *Cancer Therapy by Hyperthermia and Radiation. Proceedings of the 2nd International Symposium held in Essen, W. Germany, June 2-4, 1977.* (Baltimore: Urban and Schwarzenberg): pp. 335-336; 1978. (2 refs)

The effects of radiotherapy (RT) alone and RT immediately before or after hyperthermia (HT) were evaluated in 54 patients with multiple cutaneous malignant lesions (mycosis fungoides, Kaposi sarcoma, malignant melanoma, lymphoma cutis, and other metastatic skin lesions). Most patients were irradiated with electrons, with an average RT time of less than 5 min. The time interval between RT and HT ranged from 2 to 5 min. Initially, a constant temperature water bath (43.5 C for 30 min) was used for HT; later an inductive radio frequency (RF) device operating at a frequency of 27.12 MHz was substituted. Temperature measurements were made with very fine gauge thermocouples using a 0.009-inch diameter sensor lead shielded in Teflon tubing (outer diameter of 0.025 inch) connected to a digital thermometer. For temper-

ature measurements, the RF power was shut off and the temperatures recorded at equilibrium, usually 5-10 sec later. The tips of the sensors were usually placed in the tumors and normal tissues at a depth of 1.5 cm. None of 29 patients treated by RT and water bath HT developed any unusual early or late normal tissue reactions compared to those treated with RT alone. In contrast, 2/25 patients treated with RT and RF inductive HT developed unusual normal tissue reactions. One patient received 400 rads x 2 of RT and two RF treatments for 30 min to a local recurrent malignant melanoma. Overlying the recurrence was a skin graft from a wide primary excision. Ten days after the initial treatment, this patient developed an acute moist reaction, which took about 4 wk to heal. The second patient developed a giant vesicle in the lower aspect of the lateral chest wall, an area where he previously underwent axillary dissection for recurrent malignant melanoma. This reaction developed after the first treatment with RT and RF HT. Thus, RF treatment may be contraindicated if the exposed area is grafted or heavily scarred. Interstitial temperature measurements indicated that the tumor tissue temperature (range, 39-46 C) was generally higher than the normal tissue temperature (range, 39-43 C) during RF heating. Among 14 patients with locally recurrent disease, 11 showed significantly prolonged local tumor control after combined RT and HT (type of HT not specified) compared with their tumor response after RT alone. Fractionated HT alone caused significant tumor regression in 9/11 patients; however, the regression was neither complete nor sustained. One patient remained disease-free 9 mo after his malignant melanotic lesion was treated with 400 rads of RT plus 30 min of RF heating x 8 in 26 days. A similar lesion in the same patient partially regressed after treatment with RT alone followed by immunotherapy with bacillus Calmette-Guerin.

#### MEETING ABSTRACTS

- 6492      CARDIOVASCULAR RESPONSE OF RATS EXPOSED TO 60-Hz ELECTRIC FIELDS (MEETING ABSTRACT). (Eng.) Hilton, D. I. (Battelle Pacific Northwest Lab., Richland, WA 99352); Phillips, R. D. *Physiologist* 22(4): 56; 1979. (0 refs)

The possible influence of exposure to high-strength electric fields on electrocardiogram (ECG) patterns, heart rates, and blood pressures that has been observed in various animal species was investigated. Sprague-Dawley rats were exposed (or sham-exposed) to 60-Hz, 80-kV/m, or 100-kV/m fields for periods through 4 mo. No significant differences were found between exposed and sham-exposed rats for any of the cardiovascular parameters examined (ECG, blood pressure, vascular reactivity) after 8 hr, 40 hr, 1 mo, or 4 mo of exposure. Ex-

posure to a 100-kV/m field for 1 hr also had no significant effect on blood pressure and heart rate measured during the exposure. Physiologic reserve capabilities were measured in rats exposed to 100 kV/m for 1 mo and then subjected to cold stress; electric field exposure had no significant effect on the animals' response to the latter. These studies cannot be compared directly with other investigations because of differences in animal species and electric field characteristics. Failure to detect any cardiovascular changes could have resulted from the elimination of secondary field effects such as microcurrent shocks, corona, and ozone.

- 6493      EFFECTS OF MICROWAVE-INDUCED HYPERTHERMIA ON THE RAT BLOOD-BRAIN BARRIER (MEETING ABSTRACT). (Eng.) Sutton, C. H. (Dept. Neurologic Surgery, Univ. Miami, Miami, FL 33152); Carroll, F. B. *Physiologist* 22(4): 121; 1979. (0 refs)

See Current Literature 5440 for description of this article.

- 6494      INHIBITION OF TUMOR GROWTH BY RADIO FREQUENCY THERAPY (MEETING ABSTRACT). (Eng.) Tazawa, K. (Dept. Surgery, Toyama Medical and Pharmaceutical University, Toyama, Japan); Abe, R.; Saito, J.; Shinbo, T.; Fujita, T.; Ito, H.; Fujimaki, M.; Saito, Y. *Proc Jpn Cancer Assoc* p. 315; 1979. (0 refs)

The effect of selective heating in a radio frequency (RF) field on experimental tumors (Sato' lung cancer and AH109A) was analyzed in rats. The RF generator had an output in excess of 500 W at a crystal-controlled frequency of 13.59 MHz. The energy was transmitted from the amplifier to an impedance matching circuit. Selective heating with RF raised the temperature in the tumors from 5 to 12 C above that of the surrounding tissue. RF therapy produced tissue necrosis or substantial regression of the experimental tumors. Local heating with RF (40-48 C, 20-30 min) resulted in regression and delay in tumor growth. Complete regression was seen in 7 of 23 rats. After treatment with RF (40-46 C, 10 min), an increase in tumor growth occasionally occurred.

- 6495      INTERACTION OF 2.45 GHZ MICROWAVE RADIATION WITH EMBRYONIC QUAIL HEARTS (MEETING ABSTRACT). (Eng.) Galvin, M. J. (Research Triangle Park, NC 27710); Lieberman, M.; McRee, D. I. *Physiologist* 22(4): 42; 1979. (0 refs)

The effects of microwave radiation were examined in Japanese quail embryos exposed during the first 8 days of development to 2.45-GHz microwaves (incident power density, either 5 or 20 mW/cm<sup>2</sup>, with 4.03 and 16.2 mW/g specific absorption rates, respectively). Ambient temperature was maintained at 37.5 C, but thermal gradients in the irradiated

embryos could not be eliminated entirely, due to possible nonuniform absorption of microwaves. Neither morphologic nor ultrastructural changes in embryonic heart and myocardial cells was observed at either exposure level. Lactate dehydrogenase and glutamic oxaloacetic transaminase activities did not differ from those in controls. Creatine phosphokinase activity was lower in the 20-mW/cm<sup>2</sup> exposure group than in the 5-mW/cm<sup>2</sup> exposure group or the controls ( $p < 0.01$ ). These data indicate that 2.45-GHz microwaves at 5 mW/cm<sup>2</sup> have no effect on the developing myocardium, however, at 20 mW/cm<sup>2</sup> the cytoplasmic enzyme content is affected.

6496 MICROWAVE INDUCED HYPERTHERMIA ± RADIOTHERAPY IN THE TREATMENT OF SUPERFICIAL HUMAN MALIGNANCIES (MEETING ABSTRACT). (Eng.) Harvey, H. A. (Dept. Medicine, Milton S. Hershey Medical Center, Pennsylvania State Univ., Hershey, PA); Lipton, A.; Lookingbill, D.; White, D.; Schelzel, D.; Stryker, J.; Sharkey, F. *Clin Res* 27(3): 583A; 1979. (0 refs)

Superficial tumors in 10 patients with metastatic cancers (breast, lung, cervix, head and neck, melanoma, and sarcoma) were treated experimentally with

2,450-MHz microwave hyperthermia alone or in combination with radiation therapy (RT) after conventional RT had proven unsuccessful in most cases. Either a dielectrically-loaded tapered or conformed wave guide applicator was used, and temperatures on the surface and within the tumor were recorded with small thermistors. The lesions (mean diameter 0.5-4 cm) were treated at 43 C for 45 min periods; regimens varied from one weekly to five daily treatments. Six of the lesions received electron beam therapy (300 rads x 12) immediately after hyperthermia. One complete response (CR), one partial response (PR, > 50% reduction), and one minor response (< 50% reduction) were observed after hyperthermia alone. Five lesions unresponsive to heat alone were subsequently treated with heat plus RT, and three CR and 2 PR were observed. In a melanoma patient with multiple metastases, three similar lesions were treated with heat alone, RT alone, and the combination therapy; PR, no response, and CR were achieved, respectively. These studies suggest that localized hyperthermia, while relatively ineffective as a single modality, is promising when used in combination with RT, particularly for treatment of recurrent lesions of epidermoid carcinoma of the head and neck and cutaneous metastases of melanoma.

# AUTHORS OF CURRENT LITERATURE INDEX

[Entry numbers followed by an asterick indicate primary authors]

ABADIR, R. 06487*	CLEARY, S F 06471*	FRIEDENTHAL, E 06411, 06483
ABF, R 06494	COHEN, B H 06464*	FUJIMAKI, M 06494
ADAMS, J W 06441*	COMM COMMER SCI TRANSPORT 06468*	FUJIMORI, M 06449*
ADBY, W F 06396	CONNOR, W G 06475	FUJITA, T 06494
ANDERSON, A P 06412*	CONSTANT, E 06425	GAGE, M L 06396
ANONYMOUS 06393*, 06398*	CONVERT, G 06482	GALLOWAY, W D 06396
ARNSTRONG, E 06431	CORDEY, J 06474	GALVIN, M J 06495*
ARTHUR, M G 06472	COREN, E 06442	GAMBERALE, F 06401
ASSENHEIM, H M 06435	DARDALHON, M 06457*	GAUTHIER, M 06416*, 06426
ATKINSON, E R 06489	DAY, P W 06490	GERBER, H 06474*
AVERBECK, D 06457	DE GROOT, K 06432	CERTICKE, D 06438*, 06486
BACHURIN, V J 06447*	DEDEKOV, A N 06417, 06418	GLUSZCO, M 06405*
BARRETT, A H 06410	DESCHAMPE, F 06437	GOULD, J L 06385
BATEMAN, J B 06459*, 06467*	DIEZEL, F 06438, 06488*	GRON, C M 06414
BELL, E L 06452	DOBERNECK, R C 06490	GUERGUIN-KERN, J 06416
BERGSTROM, S 06401	DOSS, J D 06490	GUGLIA, N G 06429*
BERNHARDT, J 06400*	DOULE, J B 06420*	GUY, A W 06396
BERTEAUD, A J 06457	DOWNS, E M 06405	HAHN, E W 06474
BICHER, H I 06430	DUFOUR, J 06482	HAND, J B 06424*
BENDER, W 06486	DUMANSKI, M D 06440	HARRAL, J 06488
BIRKE, F 06401	DURNEY, C H 06443, 06455*	HARRISON, W H 06421
BIRCH, J 06412	EDRICH, J 06415*, 06416, 06426	HARVEY, R A 06495*
BIRRELL, G 06425, 06426	EDWARDS, W S 06490	HATTIHOFF, J 06441
BIRNBAUM, M 06475	ELDER, J A 06396	HAYNES, F 06401
BOISTEIN, J 06411, 06481	ELLIOTT, R S 06421	HEINRICH, M 06415
BOWEN, F G 06475	EPHARDT, W 06425	HEPPE, J 06425
BROWN, R H 06412	ERSHOV, E K 06440	HESTON, J 06425, 06474
BURNEY, F 06407*	ESCANVE, J P 06474	HERTZ, E S 06474
CABRILLO, F B 06422	FAHIM, M 06487	HELM, E W 06474
CALDWELL, J 06474	FELDMAN, J 06487	HELM, E W 06474
CHEM, K H 06456	FENTON, J S 06474	HELM, E W 06474
CHUNG, A Y 06474, 06485	FREY, A H 06482*	HELM, E W 06474

AUTHOR INDEX

Biological Effects of Nonionizing Electromagnetic  
Radiation IV(3), March 1980

HUME, S. P. 06424	KOLMODIN-HEDMAN, B. 06401	MURTON, D. L. 06421
HURLUCK, E. T. 06391*	KOWAL, N. S. 06430, 06481	MOSCHETTO, V. 06413
HYMNEN, U. 06419*	KUBOTA, S. 06449	MUSIL, J. 06450*
HYNYNEN, K. 06441	LANCASHIRE, R. 06431	MYERS, P. C. 06410*
TREGREN, A. 06401	LARKIN, J. M. 06490	NGUYEN, D. D. 06423*
ISHAY, J. S. 06370	LARSEN, L. C. 06444*	NEELAKANTASWAMY, P. S. 06445*, 06452*
ISKANDER, M. F. 06443*, 06455	LEBOURGEOIS, J. P. 06482*	NEUDER, S. M. 06469*
ITO, H. 06494	LEHMANN, E. J. 06463*	O'BRIEN, G. F. 06490
IWANO, K. 06439	LEROY, Y. 06413, 06425	OSIERA, R. 06489*
JACKSON, R. W. 06439	LIBERMAN, M. 06495	PAGIONE, R. 06411
JACURI, J. H. 06444	LIN, C. C. 06460*	PALS, M. 06458*
JANTAK, M. 06476	LINDAHL, K. 06388*	PELLISSIER, J. F. 06437
JURANEK, J. 06399*	LINHART, G. 06483	PENNY, J. W. 06462*
JOHNSON, C. C. 06433, 06455	LINKO, P. 06441*	PERREN, S. M. 06474
JOHNSON, R. J. 06430*, 06477*, 06481	LIPTON, A. 06496	PETERS, W. J. 06439*
JOHNSON, R. K. 06456	LITVINOV, N. N. 06395	PETLIN, V. G. 06436*
JUNG, P. 06434	LLEWELLING, R. E. 06391	PETROWICZ, J. O. 06425*
JURGENSEN, D. R. 06478*	LOCKY, M. W. 06403*	PHILLIPS, R. D. 06465, 06497
KANDA, M. 06448	LOOKINSHILL, D. 06496	PINIGIN, M. A. 06395
KANZENBACH, J. 06422	LOPATIN, V. F. 06417*, 06418*	POWELL, T. D. 06490
KAPULISEVICH, J. G. 06436	LOS, J. F. 06440	PREMPRE, I. 06485
KARCHER, K. H. 06497	LUEDEKE, K. M. 06422*	PRESTON, E. 06435*
KERR, H. 06409	MAGIN, P. I. 06456*, 06489	PROKOROV, I. 06486
KIRKITT, R. 06449	MAMQUIN, A. 06413*, 06423	RAGAN, H. A. 06465*
KIM, J. H. 06491*	MANNA, E. J. 06492*	RAIL, D. F. 06495
KIRSCHVINK, J. I. 06389	MARIGLI, D. J. F. 06424	RAMAKRISHNAN, K. R. 06445
KLEIN, K. 06390*	MASSOUDI, H. 06455	REITER, L. R. 06396
KLEINER, H. C. 06427*	MCQUEEN, J. F. 06484	RETTIG, C. F. 06454*
KNAVE, R. 06401	MOREE, D. J. 06496*, 06441*, 06497*	RISH, W. R. 06402*
KNOX, J. G. 06421*	MELEK, M. 06417	ROBERT, D. 06427*
KOHLER, J. 06422	MENDEL, J. J. 06411*, 06483*	ROBERT, J. 06416, 06425
KOGLINIK, G. D. 06486	MORGAN, M. C. 06402	ROBINSON, J. F. 06424, 06479, 06481



ROBINSON, J. E. (Cont.)  
06485  
ROSENSTEIN, L. S.  
06396  
RUDNIN, M. I.  
06440  
RUSTER, I.  
06438  
SADOWSKY, N. L.  
06410  
SAITO, J.  
06494  
SAITO, Y.  
06474  
SAHARAS, G. M.  
06484, 06485\*  
SANDHU, T. S.  
06420, 06481\*  
SANTINI, R.  
06437  
SCHABRA, P. E.  
06395\*  
SCHLITZEL, D.  
0649\*  
SCHMITZ-NILVERBURG, K. P.  
06409  
SCHNENHAGE, A. A.  
06458  
SCHNEMACHER, L.  
06486  
SHAFER, J.  
06443  
SHANDALA, B. G.  
06440\*  
SHARKEY, E.  
06476  
SHILYGINA, N. M.  
06429  
SHINKO, I.  
06454  
SHURE, M. I.  
06396  
SIDORENKO, G. I.  
06395  
SLAWSON, R. G.  
06485  
SMITH, P. A.  
06437

SOLOIN, L. R.  
06397\*  
SONG, S. Y.  
06430  
STABLES, L. M.  
06391  
STAVROU, D.  
06434  
STERNHAGEN, C. J.  
06420\*  
STERZER, F.  
06411  
STORM, J. K.  
06421\*  
STROHBEHN, J. W.  
06420  
STRYKER, J. L.  
06496  
STURMER, K. M.  
06409\*  
SUBJECK, J. P.  
06430  
SUSS, M. J.  
06394\*  
SUTTON, C. H.  
06493\*  
SZMIGIELSKI, S.  
06476\*  
TAGGART, H. E.  
06445  
TAYLOR, L. S.  
06480\*  
TAZAWA, K.  
06494\*  
THOUVENOT, P.  
06426  
TOKITA, N.  
06491  
TOLER, J. C.  
06472  
TSAI, H. K.  
06470\*  
TUMA, M.  
06446\*  
VAN DER KUIJL, F.  
06432\*  
VAVASOUR, E. J.  
06435

VIANCOUR, T. A.  
06451\*  
VINAKRAJA, E. I.  
06452  
VINGEHLING, F. A.  
06432  
VINOGRADOV, G. I.  
06452\*  
VON ARDENNE, R.  
06478\*  
WALCOTT, L.  
06389\*  
WALL, R.  
06431  
WALSH, J. E.  
06420  
WANG, J. H.  
06428  
WATSON, J.  
06406\* 06490\*  
WENNER, A.  
06401  
WESTERHOF, D. P.  
06433\*  
WHITE, J.  
06494  
WISLAND, J.  
06419  
WILBE, J. A.  
06433  
WONG, S. H.  
06432  
WINTER-LUBBE, J.  
06425  
YANG, W. J.  
06428\*  
YOSHIOKA, R.  
06449  
ZANKER, F. S.  
06434\*  
ZARET, M. M.  
06404\*  
ZIMMER, R.  
06411\* 06411\*

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